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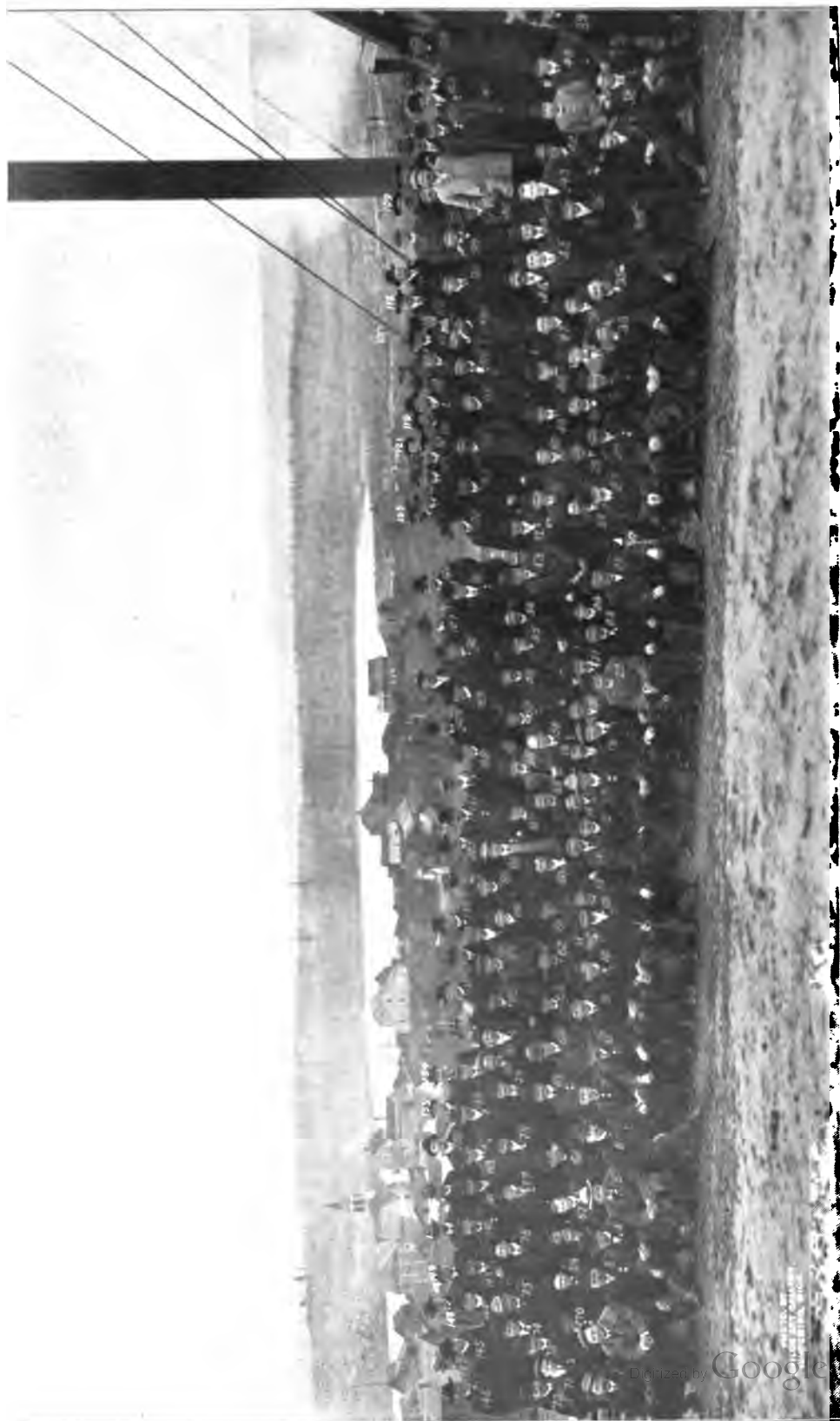
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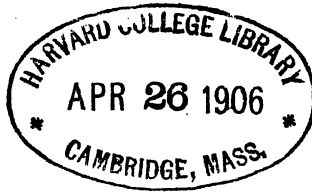
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BENNETT, JAMES H.....	
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BAWDEN, JOHN T.....	1899
BROOKS, T. B.....	1902
CONRO, ALBERT.....	January 10th, 1901
DANIELS, JOHN.....	September 13th, 1898
DICKENSON, W. E.....	June 15th, 1899
DUNSTON, THOMAS B.....	
DUNCAN, JOHN.....	June, 1904
HOLLEY, S. H.....	July 4th, 1899
HARPER, GEORGE VANCE.....	March, 1905
HAYDEN, GEORGE.....	July 27th, 1902
HOUGHTON, JACOB.....	December 30th, 1903
HINTON, FRANCIS.....	1896
HOLLAND, JAMES.....	September 3rd, 1900
HYDE, WELCOME.....	
JOCHIM, JOHN W.....	January 17th, 1905
LUSTFIELD, A.....	May 26th, 1904
LYON, JOHN B.....	February 13th, 1900
MARR, GEORGE A.....	March, 1905
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RYAN, EDWARD.....	1901
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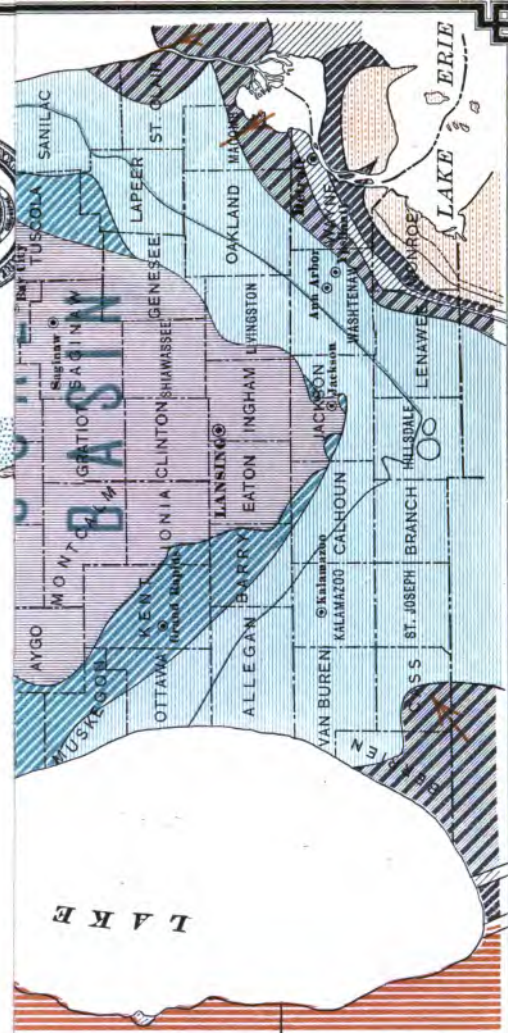
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1	Iron Mountain, Mich.....	March 22-23, 1893,	Vol. I
2	Houghton, Mich.....	March 7-9, 1894,	Vol. II
3	Mesabi and Vermillion Ranges.....	March 6-8, 1895,	Vol. III
4	Ishpeming, Mich.....	August 18-20, 1896,	Vol. IV
5	Ironwood, Mich.....	August 16-18, 1898,	Vol. V
6	Iron Mountain, Mich.....	February 6-8, 1900,	Vol. VI
7	Houghton, Mich.....	March 5-9, 1901,	Vol. VII
8	Mesabi and Vermillion Ranges.....	August 19-21, 1902,	Vol. VIII
9	Ishpeming, Mich.....	August 18-20, 1903,	Vol. IX
10	Ironwood, Mich.....	August 16-18, 1904,	Vol. X
11	Iron Mountain, Mich.....	October 17-19, 1905,	Vol. XI

Lake Superior
 Isle Royale
 Keweenaw
 Keweenaw Peninsula

Geological Map of Michigan



Scale: 1-in. equals 66 miles.
 Edition for 1905



- minerals and limestone, gas (f) and water in subordinate sandstones.
 Muskegon, including *Holston*, *Solms*, *Dundee*. Dolomite with rock salt, gypsum, glass-sand, strontium minerals, brines and mineral waters.
- In Monroe County the full line indicates the course of the Sylvan sandstones, the dotted line a bed of collite.
- ## DEVONIAN
- Dundee**, *Crossed*, *Upper Holston*, *Mineral* (naphthene) water, oil and gas signs, limestone for chemical uses.
Traverse, *Holston* and *Meredith*. Some pure limestone in reds, some dolomite, much blue argillaceous limestone, shales, cement material, oil and gas signs.
Aurifer, *Ohio*, *New Albany*, *Green*, *Peliger* and *Cleavage*. Mainly black shales, often bituminous and cause of vein effusions for coal, oil and gas.
- ## CARBONIFEROUS
- Besse** Gilt, marked by line between *Caldwells* and *Aurifer*. Sandstone, good brines, and signs of oil and gas.
Caldwells, *Waverly* and *Besse*, *Copeland*. Shales, valuable for Portland cement and brick.
Marshall, *Tenderfoot* (f), *Lepus*. Fresh water, brines, and bituminous sandstone and gneiss.
Grand Rapids, *Marcell*, *St. Louis* above, *Argus*, *Kobuk* (f) below. Limestone above, gypsum, shales and hydraulic limestone below.
Saginaw, *Pittsford*, *Millstone Grit*. Coal, paving brick, clays and shales, sandstone, etc.



RULES OF THE INSTITUTE.

I.

OBJECTS.

The objects of the Lake Superior Mining Institute are, to promote the arts and sciences connected with the economical production of the useful minerals and metals in the Lake Superior region, and the welfare of those employed in these industries, by means of meetings for social intercourse, by excursions, and by the reading and discussion of practical and professional papers, and to circulate, by means of publications among its members, the information thus obtained.

II.

MEMBERSHIP.

Any person interested in the objects of the Institute is eligible for membership.

Honorary members not exceeding ten in number, may be admitted to all the privileges of regular members except to vote. They must be persons eminent in mining or sciences relating thereto.

III.

ELECTION OF MEMBERS.

Each person desirous of becoming a member shall be proposed by at least three members, approved by the Council, and elected by ballot at a regular meeting (or by ballot at any time conducted through the mail, as the Council may prescribe), upon receiving three-fourths of the votes cast. Application must be accompanied by fee and dues as provided by Section V.

Each person proposed as an honorary member shall be recommended by at least ten members, approved by the Council, and elected by ballot at a regular meeting, (or by ballot at any time conducted through the mail, as the Council may prescribe, on receiving nine-tenths of the votes cast.

IV.

WITHDRAWAL FROM MEMBERSHIP.

Upon the recommendation of the Council, any member may be stricken from the list and denied the privilege of membership, by the vote of three-fourths of the members present at any regular meeting, due notice having been mailed in writing by the Secretary to him.

V.

DUES.

The membership fee shall be five dollars and the annual dues five dollars, and applications for membership must be accompanied by a remittance of ten dollars; five dollars for such membership fee and five dollars for dues for the first year. Honorary members shall not be liable to dues. Any member not in arrears may become a life member by the payment of fifty dollars at one time, and shall not be liable thereafter to annual dues. Any member in arrears may, at the discretion of the Council, be deprived of the receipt of publications or be stricken from the list of members when in arrears six months; Provided, That he may be restored to membership by the Council on the payment of all arrears, or by re-election after an interval of three years.

VI.

OFFICERS.

There shall be a President, five Vice-Presidents, five Managers, a Secretary and a Treasurer, and these Officers shall constitute the Council.

VII.

TERM OF OFFICE.

The President, Secretary and Treasurer shall be elected for one year, and the Vice-Presidents and Managers for two years, except that at the first election two Vice-Presidents and three Managers shall be elected for only one year. No President, Vice-President or Manager shall be eligible for immediate re-election to the same office at the expiration of the term for which he was elected. The term of office shall continue until the adjournment of the meeting at which their successors are elected.

Vacancies in the Council, whether by death, resignation, or the failure for one year to attend the Council meetings, or to perform the duties of the office, shall be filled by the appointment of the Council, and any person so appointed shall hold office for the remainder of the term for which his predecessor was elected or appointed; Provided, That such appointment shall not render him ineligible at the next election.

VIII.

DUTIES OF OFFICERS.

All the affairs of the Institute shall be managed by the Council except the selection of the place of holding regular meetings.

The duties of all Officers shall be such as usually pertain to their offices, or may be delegated to them by the Council.

The Council may in its discretion require bonds to be given by the Treasurer, and may allow the Secretary such compensation for his services as they deem proper.

At each annual meeting the Council shall make a report of proceedings to the Institute, together with a financial statement.

Five members of the Council shall constitute a quorum; but the Council may appoint an executive committee, business may be transacted at a regularly called meeting of the Council, at which less than a quorum is present, subject to the approval of a majority of the Council, subsequently given in writing to the Secretary and recorded by him with the minutes.

There shall be a meeting of the Council at every regular meeting of the Institute and at such other times as they determine.

IX.

ELECTION OF OFFICERS.

Any five members not in arrears, may nominate and present to the Secretary over their signatures, at least thirty days before the annual meeting, the names of such candidates as they may select for offices falling under the rules. The Council, or a committee thereof duly authorized for the purpose, may also make similar nominations. The assent of the nominees shall have been secured in all cases.

No less than two weeks prior to the annual meeting, the Secretary shall mail to all members not in arrears a list of all nominations made, and the number of officers to be voted for in the form of a letter ballot. Each member may vote either by striking from or adding to the names upon the list, leaving names not exceeding in number the officers to be elected, or by preparing a new list, signing the ballot with his name, and either mailing it to the Secretary, or presenting it in person at the annual meeting.

In case nominations are not made thirty days prior to the date of the annual meeting for all the offices becoming vacant under the rules, nominations for such offices may be made at the said meeting by five members not in arrears, and an election held by a written or printed ballot.

The ballots in either case shall be received and examined by three tellers appointed at the annual meeting by the presiding officer; and the persons who shall have received the greatest number of votes for the several offices shall be declared elected. The ballot shall be destroyed, and a list of the elected officers, certified by the tellers, shall be preserved by the Secretary.

X.

MEETINGS.

The annual meeting of the Institute shall be held at such time as may be designated by the Council. The Institute may at a regular

meeting select the place for holding the next regular meeting. If no place is selected by the Institute it shall be done by the Council.

Special meetings may be called whenever the Council may see fit; and the Secretary shall call a special meeting at the written request of twenty or more members. No other business shall be transacted at a special meeting than that for which it was called.

Notices of all meetings shall be mailed to all members at least thirty days in advance, with a statement of the business to be transacted, papers to be read, topics for discussion and excursions proposed.

No vote shall be taken at any meeting on any question not pertaining to the business of conducting the Institute.

Every question that shall properly come before any meeting of the Institute, shall be decided, unless otherwise provided for in these rules, by the votes of a majority of the members then present.

Any member may introduce a stranger to any regular meeting; but the latter shall not take part in the proceedings without the consent of the meeting.

XI.

PAPERS AND PUBLICATIONS.

Any member may read a paper at any regular meeting of the Institute, provided the same shall have been submitted to and approved by the Council, or a committee duly authorized by it for that purpose prior to such meeting. All papers shall become the property of the Institute on their acceptance, and, with the discussion thereon, shall subsequently be published for distribution. The number, form and distribution of all publications shall be under the control of the Council.

The Institute is not, as a body, responsible for the statements of facts or opinion advanced in papers or discussions at its meetings, and it is understood, that papers and discussions should not include personalities, or matters relating to politics, or purely to trade.

XII.

AMENDMENTS.

These rules may be amended by a two-thirds vote taken by letter ballot in the same manner as is provided for the election of officers by letter ballot; Provided, That written notice of the proposed amendment shall have been given at a previous meeting.

MINUTES OF THE ELEVENTH ANNUAL MEETING.

A social gathering of a number of mining men from the Gogebic and Menominee ranges, held at Ironwood, Michigan, on February 2nd, 1893, was the nucleus of the present Institute. A resolution presented on this occasion resulted in the first meeting being held at Iron Mountain on Wednesday and Thursday, March 22nd, and 23rd, 1893, for the purpose of perfecting an organization. Mr. William Kelly was chosen secretary at the Ironwood meeting, and circulars were sent to the mining men of the different ranges, explaining the purposes of the meeting and inviting them to attend and assist in its formation. This invitation met with universal approval and the call for the meeting was responded to by more than one hundred and sixty of the representative mining men from the iron and copper ranges of the Lake Superior district. Many of those who could not attend sent messages of encouragement to the promoters.

At this meeting held twelve years ago, the Lake Superior Mining Institute was started. The benefits to its members are innumerable, affording, as it does by its annual meetings to the different ranges, the opportunity for the inspection of the work carried on, and the pleasure of the social features attending. The reading of papers which are provided by its members, has always proven an interesting feature, bringing out their best thoughts and one that should be much encouraged owing to the great benefits which result therefrom, not only to those in attendance, but to the students of mining in this and other districts. These papers, in order that they may be of the greatest value, should be published and distributed at an early date before the annual meetings, so that by a careful study of the subject an intelligent discussion may be held. This oftentimes

brings out many important points overlooked in the preparation of the original paper, and is of great assistance to the student.

The methods employed in mining on the different ranges, where conditions vary as they do throughout the Lake Superior district, are of much interest to the mining man. The field that may be covered by carefully prepared papers is a large one. We have many features pertaining to the mining and mechanical departments that can be made interesting subjects for papers for this Institute, and the same would bring out a general discussion. Then we should not overlook the great army of men employed above and below ground, who dig and handle the vast output from the Lake Superior iron and copper mines yearly. The question of their health and safety is an important one, and worthy of much careful thought and consideration. The housing of the families of the miners, the education of their children and the provision of means for their recreation and enjoyment, is a question which must not be treated lightly in connection with the general welfare of those engaged in the mining industry. At many of the mines outside of the larger cities and villages where the people are obliged to live at the location, club rooms might be provided and fitted up for the enjoyment of the men, they could also be made attractive and interesting for the ladies and children by various forms of entertainment, all tending to the betterment of their social condition. Much is being done along these lines by many of the larger concerns throughout the country, and much more can be done. While the Lake Superior Mining Institute has accomplished much in its brief and useful career, there is yet work enough ahead to insure its success and importance for many years to come.

The organizers planned well at their social gathering at Ironwood on February 2nd, 1893, and the results must indeed be very gratifying to them. Meetings have been held each year since its organization, excepting 1897 and 1899. During the depression in the iron business it was often with difficulty

that a sufficient number were gotten together. Many of the mines had closed and the members gone to the western fields and were unable to be present. However, the order of visiting the ranges in turn has been kept up, and the eleventh meeting finds us for a third time at Iron Mountain, where the first regular meeting was held on the occasion of the Institute's permanent organization.

The following program arranged by the local committee was carried out as far as weather would permit. Owing to the rain on Tuesday and the condition of the roads, it was thought advisable to cut out the visit to the electric power plant which is being erected by the Penn Iron Mining company at Sturgeon Falls, near Vulcan:

Tuesday, October Seventeenth.

Members will assemble at the Commercial Hotel Iron Mountain, at 9:00 o'clock a. m., and will proceed on foot to the Chapin mine, where an opportunity will be afforded to inspect the various plants. Party will then proceed "over the hill," from which an excellent view of the city and surrounding country may be secured, enroute to the Walpole and Pewabic mines. After inspecting these properties, the members will take a special train at the Pewabic mine, leaving promptly at 12 o'clock, noon, for Florence, Wis., where the party will be received by the Florence-Iron River company. At 1:00 o'clock p. m., train will leave Florence for Crystal Falls, where the remainder of the afternoon will be occupied in visiting the Tobin and Great Western mines. Supper will be served at the Lockwood House. At 8:00 o'clock, the evening session will be held in the Iron county court house, at which papers will be read by Mr. L. Battu, of Chicago, and others. At 11:00 o'clock p. m., a special train will leave Crystal Falls for Vulcan and intermediate points.

Wednesday, October Eighteenth.

Special train will leave Crystal Falls at 7:00 o'clock a. m., and Iron Mountain at 8:30 a. m., for Vulcan, returning to Iron Mountain at 3:30 p. m., and proceeding via the Chicago, Milwaukee & St. Paul railroad to the Traders mine. At Vulcan carriages will convey the party to Sturgeon Falls, where the Penn Iron Mining company is constructing a large electric power plant for the operation of their mines. Train will also stop enroute to Iron Mountain at the Munro mine. At 8:00 o'clock, an evening session will be held at the Dickinson county court house, where papers will be read by members; also the annual election of officers and business conference. At 11:00 p. m. special trains will

leave for Crystal Falls and Vulcan, to accommodate members desiring to spend the night at home.

Thursday, October Nineteenth.

A special train will leave Crystal Falls at 7:00 o'clock a. m., and Iron Mountain at 8:30, for Escanaba, and will proceed directly to the ore crushing plant of the Oliver Iron Mining company; thence to the tie preserving plant of the Chicago & Northwestern Railway company; thence to the merchandise dock, where the party will embark on the steamer "Maywood" for a trip to the ore and coal docks; thence by steamer to Gladstone. At the latter place the large charcoal furnace and by-product plant of the Pioneer Iron company will be visited. Steamer will return party to Escanaba at 5:30, and supper will be served at the hotels in time for members to leave on their special trains for home. Train for the Marquette range and the copper country will leave Escanaba in time to connect at Negaunee with train No. 7 on the Duluth, South Shore & Atlantic railroad. Train for Menominee range points will leave Escanaba at 9:00 o'clock p. m.

TUESDAY, OCTOBER 17TH, 1905.

Members and guests began to arrive on the evening trains Monday and by Tuesday forenoon, the 17th, there were assembled nearly 200 people, more joining the party at the different towns visited until the total number in attendance represented 250 members and guests. The party assembled at the Commercial Hotel where badges were furnished and sleeping accommodation secured. Owing to the facilities at the hotels being inadequate for so large a gathering, sleeping cars had been provided and were placed on a siding near the hotel so that all were comfortably taken care of.

The badges selected by the committee in charge was the subject of much favorable comment. From the bar which bore the date, 1905, was suspended an oval plate in which the name of the wearer was inserted. This idea is unique, as it does away with the embarrassment of getting names and faces confused. Below the name plate and fastened to the lower end of the ribbon was a medallion with the letters L. S. M. I. worked into a monogram. On the opposite side in raised letters was inscribed the range and date of meeting.

Local committees were appointed to take charge of arrangements and were composed of the following members:

Entertainment—William Kelly, William J. Richards Charles E. Lawrence, Otto C. Davidson.

Finance—Felix A. Vogel, Edward W. Hopkins.

Transportation—Elwin F. Brown, Otto C. Davidson.

Crystal Falls Local Committee—Arvid Bjork, William Trebilcock.

Promptly at nine o'clock the party left the hotel for a visit to the Chapin mine. The day was decidedly disagreeable, a drizzling rain falling which dampened the clothing, but not the ardor of the party. The large and well equipped shop was first visited and some little time was spent here.

Attracting the attention of the party as they approached the Chapin was the big fill made to keep open the county roadway and railway tracks crossing the company's lands. This is probably 600 feet long and of a width to permit of the highway and a double railway track. A sand train is kept busy on the latter work, while teams are constantly drawing earth to protect the roadway. The mining of large deposits of ore underneath accounts for the settling of the surface and is not an uncommon occurrence in Lake Superior iron mining districts.

The Chapin is mining vigorously at a depth of 900 feet below these roadways, and has still a large amount of ore to extract so that the unusual surface expense at this point will have to be continued that traffic may not be disturbed. The great depression to the east and west of this fill plainly marks the course of the company's principal underground operations.

Near this roadway, at D shaft, was formerly located the mine's principal pumping station where was installed an enormous steeple compound pumping engine. A few years ago the station was abandoned and the pump removed, since which time it has been idle. The big pump is to again be installed, however, a foundation for it now being prepared at "C" shaft now sinking several hundred feet to the west, and on property formerly embraced in the Ludington company's lands.

Leaving the shops the party proceeded to the new shaft known as "C" Ludington. This shaft was commenced about two years ago and has reached a depth of 1,125 ft. It is vertical and has two skip and one cage compartments with another for

pumps, ladders and counterweights. The inside dimensions are 10'4"x23'1", and the shaft is one of the largest in the Iron country. It is about 700 feet back in the footwall, thus insuring it against "drawing" by caving due to the removal of the ore. The method of securing this shaft by steel sets is fully described by Mr. Frank Drake in his paper on "The Use of Steel in Lining Mine Shafts," published on pages 43-44 of volume VIII, 1902. Owing to the size of the shaft some changes in connecting the sets from those used at other mines had to be introduced here.

Hamilton shaft No. 2 and Ludington "B" were also visited and much that was interesting was brought to the attention of the visitors. The Chapin is the "big" mine of the Menominee range, they will send out about 1,000,000 tons for the year 1905, and are employing nearly 1,000 men. The property is now operated by the Oliver Iron Mining Co., Mr. O. C. Davidson, general superintendent. It was first opened in 1879.

Reference is here made to an experience with water in sinking Hamilton shaft, as described in a paper by Mr. James MacNaughton, published on pages 37 to 43 of Vol. VI, 1900, the title being "Mine Dams." After completing the rounds of the Chapin, the special train placed at the disposal of the Institute by the Chicago & Northwestern Railway Co. was taken for the Pewabic mine. It had been intended to have walked over the big hill from the Chapin, from which a fine view of the town and surrounding country could have been obtained, but the rain prevented, rendering the road slippery and disagreeable.

No. 1 shaft of the Pewabic is the principal one of the old mine workings. It is 950 feet deep and has seven levels. About 1,500 gallons of water are being raised and is cared for by a Prescott triple expansion pumping engine with 15-inch water column. A test shaft is down 200 feet in the south formation and will be continued so as to put in exploring drifts that will practically test the immediate vicinity. The Pewabic is controlled by the Pewabic Mining Co., and the Carnegie

Steel Co., Mr. E. F. Brown, manager. The first shipment was made in 1890.

The Walpole, the property of the Pewabic company, and immediately adjoining the latter is giving a fair amount of ore, this coming principally from No. 2 shaft which is 710 feet deep. A Sullivan hoisting plant with a rope of 2,250 feet does business at this station. It attracted considerable attention from the members. This mine is to be supplied with an electric underground tram system this winter, which will be a great improvement in the handling of its output.

Next season the concentrating plant of the company, located at the Keel Ridge mine is to be started again, it having been idle several years. The ore is associated with sandstone and limestone.

The limestone is frequently met in the underground workings of the Walpole. Immense masses, detached from the adjoining regular formation are often encountered, sometimes being of such size as to lead the miners to believe they are solid ledge. The Walpole is kept going by constant exploring with drills and openings. Indeed this is more or less true of all the iron mines of the older ranges. Leaving the Pewabic the special train proceeded for the western end of the range, lunch being served en route, and was much enjoyed by the hungry party.

The next stop was made at the Florence mine, Florence, Wisconsin. This is one of the old mines of the Menominee range and was idle for several years. It is controlled by Ladenburg-Thalman & Co., of New York, and Mr. Felix A. Vogel is general manager. The ore bodies are quite extensive but of low iron content, and high in phosphorus. No. 7 is the principal shaft and has a depth of about 800 feet. Diamond drilling is being carried on in search of other ore bodies. Light refreshments were served which was much enjoyed by the party.

Leaving Florence, the party proceeded to Crystal Falls, the first stop being made at the Tobin mine. This property is op-

erated by the firm of Corrigan-McKinney Co., of Cleveland. The new shaft is about 700 feet deep, and is well equipped to handle a large tonnage. The mine is working on the caving system which gives very satisfactory results. A new hoisting and compressor plant has just been installed, and the mine is being equipped with an electric tram plant. The first shipment made by the Tobin was 18,957 tons in 1901, although the mine was previously operated by another company before coming into the hands of its present owners. The large amount of new work at this property indicates that the company have faith in the ore deposits so far disclosed, and the prospects of other bodies still hidden.

The Great Western mine also operated by the Corrigan-McKinney Co., was next visited. This mine like many others has had its ups-and-downs but is now in better shape. A large cave occurred which practically stopped operations for the time being. Since the new shaft went into commission and improved methods of mining were inaugurated everything has progressed nicely, and the mine has great promise of large products. Many of the mines in the Crystal Falls district have suffered by periodical stoppages due to depression in the iron business which have occurred from time to time in the past. Several have changed in ownership so that it is with great difficulty that the history can be traced back to the original discovery, and the various names applied by former operators. Mr. William J. Richards, general superintendent of the Corrigan-McKinney Co., makes his headquarters at Crystal Falls, and is assisted by William Fraser, assistant superintendent, who looks after the Menominee range properties of this concern. There was not time to visit any of the other mines of the Crystal Falls group, so the party repaired to the Hotel Lockwood for supper.

EVENING SESSION.

At 8:00 o'clock p. m. the Institute met at the Iron county court house where the first business session was held. The

meeting was opened by President O. C. Davidson, who made the address of welcome in behalf of the members of the Menominee range.

Members of the Institute and Guests: In behalf of the members resident on the Menominee range I extend to you a most cordial welcome. I would say, however, the invitation to hold the meeting here was extended with many misgivings for we feared that we would not be able to show you much in the way of mines, or mine equipment that would interest you, because two meetings have already been held on this range and most of you are probably quite familiar with our plants, neither have we the facilities to entertain you socially as we desire.

Personally I advocated the postponement of the meeting until next year in the hope that we would then be able to arrange a more interesting program, as the concentrating plant of the Pewabic company will, I understand, probably be in operation next summer. This plant was fully described in a paper by Mr. Hardenburg and read at one of our meetings, but I think few members have seen the plant in operation and as it is the only plant for the concentration of iron ore in the Lake Superior region it is unusually interesting. The Penn Iron Mining company will have running the hydraulic power plant at the Sturgeon Falls which they recently started to construct and where they will generate power to almost entirely eliminate the use of steam at their mines in Vulcan and Norway. We think that even the work preliminary to harnessing and utilizing this fine water power will be interesting and arrangements have been made to visit it tomorrow.

The large Cornish pump formerly in use at "D" shaft, Chapin mine, and which was dismantled some years ago on account of the caving of the shaft, will be installed in a new shaft and will be pumping from 2,900 to 3,000 gallons of water per minute from a depth of 1,400 feet. There will doubtless be other interesting things to show next year in the Crystal Falls and Iron River districts that we do not now have.

I was so convinced that it would be for the best interests

of the Institute to postpone the meeting until next year that I argued this course to the best of my ability, until my friend Duncan accused me of wishing to retain the presidency of the Institute another year in order to draw the salary as long as possible.

Advice—probably better than my own—prevailed and I am now glad to see you here, and hope that though we are not able to show you anything new, you will, nevertheless derive much pleasure in meeting and discussing with our fellow-workers in a most informal way matters of mutual interest and that you will not regret that you have taken time to attend this meeting of the Institute.

I believe that the greatest benefit of these meetings, after all, is in the opportunities that they give us to meet and become acquainted with each other, or to become better acquainted and to have little heart to heart talks in which we tell of our trials and tribulations, and to learn that others have troubles also, and that we are not the only ones whose ore is too low in iron or too high in phosphorus, silica, manganese, sulphur or something else; whose ores are too hard, or too soft, whose capping and hanging wall is so hard that it will not cave as wanted, or whose walls are so soft that it is impossible to keep drifts and crosscuts open because the pressure is so great that no timber will stand but a short time. There are innumerable difficulties that must be met and if one remains at home he is apt to think that he is getting more than his share of trouble. It is said that misery loves company, but that does not mean that it gives us pleasure to see others in trouble, but the fact that others have difficulties and disappointments and overcome them, gives one courage to continue their contests when the odds against them seem almost overwhelming.

I think all mine superintendents in the Lake Superior districts have cause to feel grateful for the ability and character of their employes, as a whole, both mechanics, miners and laborers are all that could be desired. They are absolutely loyal to their employer, fearless in times of danger and unsparing of

their brawny muscles in the hard work that is called for in mining operations.

The power drills, steam shovels and haulage plants have reduced the hard work of mine employes somewhat, but there is still much work that can only be accomplished by severe manual labor throughout the day. There are, of course, among mine employes, those who are merely looking for pay day, but they are the exception and it is one of the duties of a mine superintendent or captain to see that the energetic, capable men do not suffer on account of the little work accomplished by the men who are always trying to shirk, for it is not possible to entirely weed out this undesirable class.

We should be quick to recognize energy and ability and remunerate it so far as lies in our power. The man who works the hardest does not always accomplish the most, but the most successful is he who uses his brain and plans his work ahead even if he is merely shoveling, and if it is advantageous to think and plan while engaged in ordinary labor, how much more necessary it is that those who have the direction of work for others, have their plans well thought out and all probable contingencies considered and provided for, so that no false moves are made or unnecessary work done. I am sure that much benefit is derived from these meetings through the discussions that come up between members as they visit the different ranges and various mines, as nearly every mine has some conditions that are peculiar to itself, and much can be learned from those who have had to meet those conditions and master them.

Mining work has been fascinating to me ever since I first engaged in it, but there are cares and sometimes anxieties that are wearing, but I always return from our Institute meetings enthusiastic and glad that my work has to do with mining. This liking extends to my family as you will see from a remark made by my youngest boy when he was four or five years old.

He said to me, "Papa when we are born we are not boys,

are we? We are just babies, then we are boys, then men, and then miners."

I thank you gentlemen for your kind attention.

Mr. L. Battu, of Chicago, read an interesting paper on the "Utilization of Exhaust Steam" by the Rateau system, giving several illustrations on the black-board. It is to be regretted that this paper was not published in advance of the meeting so as to have brought out a general discussion. Mr. S. F. Nelson, superintendent of the Sullivan Machinery Co., asked the speaker with reference to several points, which discussion is published in this volume.

Mr. W. A. Siebenthal, of Republic, prepared a valuable paper on the "Methods of Iron Ore Analysis Used in the Lake Superior Mining District." As the paper itself was intended only for publication in the proceedings, Mr. Siebenthal had prepared a synopsis of the subject which was received with much interest.

Mr. Floyd L. Burr, of Vulcan, presented a paper on "The Method of Surveying for Secondary Mine Openings." Illustrations were drawn on the black-board explaining clearly the particular points referred to. The paper was very interesting and is published in this volume. This concluded the reading of papers for the evening and the business of the session was then taken up.

On motion the president appointed the following committees:

On Nomination: William Kelly, David T. Morgan, Norman W. Haire, William J. West, Herman F. Ellard.

On Auditing: George J. Eiseley, William G. Monroe and Robert E. Mace.

Committees were instructed to report at the session Wednesday evening.

The president then announced the program for the next day, calling attention to some slight changes in the train schedule. The Iron County Mining club extended to the Institute and its guests an invitation to a lunch and smoker at the opera



PENN IRON MINING CO., VULCAN, MINE, VULCAN, MICH.



PENN IRON MG. CO., VULCAN, MINE, VULCAN, MICH.



TIE PRESERVING PLANT OF C. & N. W. RY. CO., AT
ESCANABA, MICH.



C. REISS COAL DOCK, ESCANABA, MICH.



OLIVER IRON MINING CO., ARAGON NO. 5, NORWAY, MICH.



REPUBLIC IRON & STEEL CO., TRADERS MINE,
IRON MOUNTAIN, MICH.



REPUBLIC IRON & STEEL CO., TRADERS MINE,
IRON MOUNTAIN, MICH.

house immediately after the close of the session. This invitation was accepted with thanks by the Institute. There being no further business the meeting was on motion adjourned to Wednesday evening at Iron Mountain.

The members with their guests assembled at the opera house for the lunch and smoker. Here they met many of the citizens of the range who were not mining men, but who nevertheless contributed much to the entertainment of the visitors, and expressed themselves as being proud to act as hosts to the Institute. The lunch was all that could be wished for and the smoker was nothing short. As the train for Iron Mountain was due to leave shortly after lunch only a few speeches were heard. Songs and stories contributed to the entertainment, and with the orchestra left no time which was not filled in. The party finally breaking up with hearty cheers for the Iron County Mining club.

WEDNESDAY, OCTOBER 18TH, 1905.

At 8 o'clock Wednesday morning the special train left Crystal Falls for Vulcan, taking on the members at the different stations who left for their homes on the late trains the night before. The weather had cleared up and the day was bright and warm. Over two hundred members and guests taking in the trip. The West Vulcan mine of the Penn Iron Mining Co., William Kelly, manager, was the first property visited, the party going through the office, shops, and change house, or dry as commonly called. This dry was one of the first of the improved type of buildings for this purpose in the iron country. A full description with photographs, was the subject of a paper by Mr. William Kelly and is published in volume VIII, pages 70 to 74. The engine houses and other buildings were also visited and the party found everything in well kept order. In connection with their electric bell signaling device, they employ a feature which to many was a decided novelty as well as a safeguard. In front of, and in plain view of the brakeman there is placed a clock-like indicator which

shows at a glance the number of bells rung. Therefore, should the brakeman not be sure of his count, the indicator acts as a check and prevents a mistake. This system is fully described and illustrated in a paper by Mr. A. W. Thompson, published in Volume VI, pages 27 to 36.

From here the party visited the Aragon mine of the Oliver Iron Mining Co., and considerable time was spent in the inspection of the plant at No. 5 shaft. The shaft house is built of steel after the type commonly used by the Steel corporation mines, a photograph is published elsewhere in this volume. The machinery plant is new and of the latest improved type. After completing the visit to the Aragon the party again boarded their train for a trip to the Traders mine, lunch being served on the cars. At Iron Mountain the train was transferred to the Chicago, Milwaukee & St. Paul railway for the run to the Traders mine. This is a large open pit proposition, with a low grade ore, but as this can be cheaply mined they are not more unfortunate than some of their underground neighbors. The property is operated by the Republic Iron & Steel company, and mining is carried on only during the season of navigation. As the ore is hoisted into the shaft house it passes through the crushers before being run into the ore cars, the conditions are ideal for cheap mining, the ore being milled to the tram cars from the open pit. The party leaving the Traders returned to Iron Mountain in time for supper.

Time did not permit a visit to the Iron River and Stambaugh mines. The last trip made to these mines by the Institute was in 1900.

EVENING SESSION.

The second business session was held at the Dickinson county court house at Iron Mountain at 8:00 p. m. The meeting was called to order by President O. C. Davidson, who introduced Mr. John L. Buell, of Quinnesec, one of the first settlers on the range. Mr. Buell read a paper entitled "The

Menominee Range" which was very interesting containing much of historical value.

Mr. John T. Jones, of Iron Mountain, presented a paper on "The Unwatering of the Hamilton and Ludington Mines." The flooding of the mines and their subsequent idleness was a blow to the little city of Iron Mountain from which it took some years to recover.

Mr. Frank H. Armstrong, of Vulvan, presented a paper illustrated with stereopticon views, the subject being "Notes on Some Recent Changes in the Equipment of the Republic Mine." The paper was very interesting, the pictures adding much in illustrating the subject.

A paper by Mr. F. A. Jansen on the "Deflection of Diamond Drill Holes," proved very interesting. Mr. Jansen has done much in a practical way in determining the course of drill holes.

Mr. Kelly: "I think it was in the shaft which Mr. Jones described this evening that there was a diamond drill hole, which it might be of interest for Mr. Jones to tell us about."

Mr. Jones: "In No. 1 Hamilton shaft there was a diamond drill hole 600 feet deep, and at that time we supposed that diamond drills were made to drill perpendicular. We received authority along about that time to sink No. 1 shaft, and we started the work over the hole in the southwest corner. When we got down 400 feet that particular hole had moved over and disappeared under the north set, came back again in the shaft, and then disappeared in the northeast corner, and we never-knew where it went."

The following papers were read by title:

"Cargo Sampling of Iron Ore Received at Lower Lake Ports, Including Methods Used in the Analysis of the same," by W. J. Rattle & Son, Cleveland, Ohio. "Card System of Accounting for Mine Supplies," by Walter M. Jeffery, Duluth, Minn.

This concluded the reading of papers.

REPORT OF THE COUNCIL.

The Council then presented its report for the fiscal year, ending October 17th, 1905.

Secretary's Report of Receipts and Expenditures from August 15, 1904, to October 17, 1905:

Receipts—	
Balance on hand August 15, 1904.....	\$2,908 82
Received for dues, 1904.....	\$1,790 00
Received for back dues.....	145 00
Received for dues, 1905.....	60 00
Received for sale of proceedings.....	65 77
Received interest on deposits.....	132 18
Total receipts.....	2,192 95
Grand total	\$5,101 77
Disbursements—	
Stationery and printing.....	\$40 98
Postage.....	91 55
Freight and express.....	18 31
Telephone and telegraph.....	1 86
Office furniture and fixtures.....	50 25
Secretary's salary	500 00
Clerical work and stenography.....	68 27
	\$771 22
Publishing proceedings Volume X—	
Printing and binding	\$531 60
Lithographing	74 23
Photos and tracings.....	7 00
Binding extra Vols. I to VI..	12 00
	\$624 83
Publishing papers in advance of last meeting.....	48 25
Expense of last meeting, stenographer, etc.....	18 50
Total disbursements.....	\$1,462 80
Cash on hand	3,638 97
Total	\$5,101 77
Membership—	
	1904 1905
Members in good standing.....	339 371
Honorary members	3 3
Life members.....	1 1
Members in arrears.....	83 57
Total	426 432
New members admitted.....	34 97
Members not qualified.....	4 9
New members added.....	30 88

A. J. YUNGBLUTH,
Secretary.

Report of the treasurer for the fiscal year ending, October 17, 1905:

Balance on hand August 17th, 1904.....	\$2,908 82	
Received from A. J. Yungbluth, secretary.....	2,060 77	
Interest on deposits.....	132 18	
		<hr/>
Paid drafts No. 1 to 35 inclusive.....		\$1,462 80
Balance on hand....		3,638 97
		<hr/>
	\$5,101 77	\$5,101 77

E. W. HOPKINS,
Treasurer.

Iron Mountain, Mich., October 18, 1905.

The undersigned committee appointed to audit the books of the secretary and treasurer, beg leave to report that they have carefully examined the same, and find them to be in accordance with the above statements.

GEO. J. EISELE,
H. G. MONROE,
R. E. MACE,
Auditing Committee.

The following list of applications for membership are approved by the Council:

Aishton, R. H., Assistant General Manager, C. & N. W. Ry., 215 Jackson Boulevard, Chicago, Ills.

Alven, G. A., Mining Captain, Norway, Mich.

Bauder, W. Ralph, Mining Engineer, Ishpeming, Mich.

Baxter, Charles Homer, Mining Engineer, Iron Mountain, Mich.

Broughton, Henry Primm, General Manager, Great Northern Power Co., Providence Bldg., Duluth, Minn.

Cram, Frederick W., Chemist, Commonwealth, Wis.

Chamberlin, H. L., Superintendent, Florence, Wis.

Carson, John A., Manufacturer, Appleton, Wis.

Clark, Horace S., Salesman, Macomber & Whyte Rope Co., 21 So. Canal St., Chicago, Ills.

Clifford, J. N., Superintendent, C., M. & St. P. Ry. ore docks, Escanaba, Mich.

Clemens, John, Mining Captain, Ironwood, Mich.

Cornell, Norman J., Broker, 106 Front St., Ishpeming, Mich.

Cundy H. J., Superintendent, Iron Ridge Mine, Iron Mountain, Mich.

Davidson, Ward F., Student, Iron Mountain, Mich.

Driscoll, Cornelius B., Superintendent Crusher Plant, Negaunee, Mich.

Dean, Dudley S., Treasurer Keweenaw Association, 37 Milk Street, Boston, Mass.

Earling, H. B., Assistant General Superintendent, C., M. & St. P. Ry., Milwaukee, Wis.

Favor, George Warren, Representing Sullivan Machinery Co., Railway Exchange, Chicago, Ills.

Fay, Joseph, Livery and Contractor, Lake Street, Marquette, Mich.

Frazer, William, Assistant Superintendent, Corrigan-McKinney Co., Crystal Falls, Mich.

Feuchere, Leon, Geologist, Ishpeming, Mich.

Fox, John Murray, Mining Engineer, Ishpeming, Mich.

Frangquist, August, Mining Captain, Crystal Falls, Mich.

Getchell, Frank H., Clerk Mohawk Mining Co., Mohawk, Mich.

Gow, A. M., Assistant Chief Engineer, Oliver Iron Mining Co., Wolvin Bldg., Duluth, Minn.

Harrison, S. N., Superintendent, Wisconsin & Michigan Railway, Peshtigo, Wis.

Harrison, G. E., Superintendent, Stevenson Iron Mining Co., Hibbing, Minn.

Hearley, Michael T., Secretary, Great Western Oil Co., Cleveland, Ohio.

Hitchens, John H., Chemist, Chapin Mine, Iron Mountain, Mich.

Huntoon, Harry A., Assistant Master Mechanic, Ishpeming, Mich.

Jensen, N. C., Cashier, Commonwealth, Wis.

Jones, John T., Mine Operator, Iron Mountain, Mich.

- Jones, A. G., Mine Superintendent, Iron Mountain, Mich.
Jones, E. W., Mine Superintendent, Iron Mountain, Mich.
Knight, J. B., Editor, Norway, Mich.
Larson, Edward, Captain, Florence, Wis.
Look, William F., Dock Agent, C. & N. W. Ry., Escanaba, Mich.
Maas, William J., Mining, Negaunee, Mich.
McDermott, Henry, Mine Superintendent, Iron Mountain, Mich.
Mead, Frank D., Lawyer, Escanaba, Mich.
Mills, John, Manager, New York Belting & Packing Co., 150 Lake St., Chicago, Ills.
McClure, O. D., Master Mechanic, C.-C. I. Co., Ishpeming, Mich.
McGregor, Silas. J., Superintendent, Millie Mine, Iron Mountain, Mich.
McLean, Richard Earle, Lumber and Lands, Wells, Mich.
Nelson, S. T., Superintendent, Sullivan Machinery Co., Chicago, Ills.
Pattberg, Otto, Mining Engineer, Florence, Wis.
Penton, John A., Publisher, Iron Trade Review, Cleveland, Ohio.
Quine, John T., Mine Inspector, 413 Vine St., Ishpeming, Mich.
Rumsey, Spencer S., Mechanical Engineer, Wolvin Bldg., Duluth, Minn.
Salomonson, H., Foreman Carpenter, Aragon Mine, Norway, Mich.
Soady, Harry, Salesman, Ingersoll-Rand Co., Iron Mountain, Mich.
Swain, Richard A., Agent, General Electric Co., Duluth, Minn.
Tufts, John W., Salesman, Goodyear Rubber Co., Milwaukee, Wis.
Tripp, Charles P., Metallurgical Engineer, Monodnack Block, Chicago, Ills.

Tarr, S. W., Civil Engineer, Wolvin Bldg., Duluth, Minn.
Townsend, C. V. R., Assistant Land Agent, C.-C. I. Co.,
Negaunee, Mich.

VanValkenburg, Allen J., Superintendent, Wisconsin
Central Railway, Abbotsford, Wis.

Wagner, John M., Purchasing Agent, Copper Range
Consolidated Co., Houghton, Mich.

Wells, Pearson, Mining Engineer, St. James Hotel, Iron-
wood, Mich.

Whitehead, R. G., Shift Boss, Amasa, Michigan.

Wilkins, William, Mining, Ashland Iron Steel Co., Ash-
land, Wis.

Winegar, Charles T. Lawyer, Iron Mountain, Mich.

Witherbee, F. S., Witherbee, Sherman & Co., Port Henry,
N. Y.

Youngs, George C., Editor, Florence, Wis.

On motion the report of the Council was adopted by the
Institute and the secretary instructed to cast a ballot for the
election of the applicants as approved by the Council for mem-
bership in the Institute.

The auditing committee reported on the examinations of
the books of the secretary and treasurer, which report follows
the financial statement presented by the Council.

Report of committee on badges, by Mr. William Kelly.
The committee on badges was appointed three years ago. Be-
fore the Marquette meeting the committee obtained a sample
pin, but it was not acceptable and the committee made no re-
port. At the Milwaukee meeting a report of progress was
made. The committee was given further time, and instructed
to recommend a design for badges to be worn at the meetings,
as well as a permanent pin. After that meeting Mr. Drake
resigned on account of absence from the Lake Superior district
and Mr. Yungbluth was appointed in his place.

The badges used at this meeting are recommended by the
committee as a suitable design to be used at successive meet-
ings of the society. The idea of the committee as to the design

for a pin has been that the base should represent a section of octagon drill steel, both in color and form and on this should be embossed in copper or in some metal resembling copper, the two symbolical mining hammers and the letters L. S. M. I. in the intermediate spaces. Two sample pins have been received embodying this idea, but they are too large and clumsy and the committee does not recommend them. The committee has also received three designs for pins from Tiffany & Co., of New York, one of which carries out the idea of the committee and the other two are modifications. The committee tried to get sample pins made after these designs, but could not get them in time for this meeting. Until the sample pins are received, the committee is not disposed to make any recommendation as a design which may look very pretty on paper may not be acceptable in the pin itself. The committee therefore, asks again for further time.

Mr. Davidson: Would it not be better to pass a resolution authorizing this committee to make a selection rather than to recommend a design. In that way we will probably be able to have something definite at the next meeting.

Mr. Amberg made a motion to that effect, which was seconded by Captain Richards, and the motion carried.

Mr. J. H. McLean: I desire to offer the following resolution: "Resolved that the hearty thanks of this Institute are hereby tendered to the officials of Iron and Dickinson counties, for the use of the court houses of said counties for our meetings, to the C. & N. W. Ry. Co., and the C., M. & St. P. Ry. Co., for the use of their trains, and to the officers of said companies, the mining companies of the Menominee range, the Iron County Mining club and the Iron Mountain club for their many courtesies and splendid entertainment." On motion the resolution was adopted.

The president then made an announcement that the train would leave for Escanaba at 8:30 sharp the next morning, and also extended to the Institute an invitation to attend a smoker at the Iron Mountain club after the meeting was over.

Report of committee on nominations.

Mr. Kelly: I beg to submit the following names as officers of the Institute for the terms specified:

For President: James MacNaughton, Calumet, Mich.

For Vice Presidents: John M. Longyear, Marquette, Mich.; F. W. Denton, Painesdale, Mich..

For Managers: James R. Thompson, Ironwood, Mich.; F. A. Vogel, Florence, Wis.

Mr. Davidson: Gentlemen, you have heard the report, what is your pleasure?

Captain W. H. Johnston moved that the report of the committee on nominations be adopted, and that the secretary cast a ballot for the names mentioned. Motion carried.

Mr. MacNaughton was not present at the evening session to receive the gavel and perform the closing exercises of the meeting, which was done by Mr. O. C. Davidson, after extending a vote of thanks to the officers and members for their assistance and hearty co-operation during his term of office.

Meeting adjourned at 10:35.

The smoker and lunch tendered by the Iron Mountain club was a very enjoyable affair, and a very pleasant evening was spent, the members meeting many of the prominent people of the city.

THURSDAY, OCTOBER 19TH, 1905.

Promptly at 8:30 Thursday morning the party started for Escanaba where the last day of the session was to be spent. Arriving there the visitors were met by a delegation of citizens from Escanaba including the mayor who extended the freedom of the city to the Institute. The first place visited was the ore crushing plant of the Oliver Iron Mining Co. To this plant is brought the ore from their mines and crushed before being loaded into the boats. The coarse ore being dumped into the crusher pocket, the same car is then loaded at the conveyor pocket with the crushed product. The plant consists of two No. 9 Gates crushers and the product is reduced to about

three inches in size. A "Robins" belt conveyor is installed to carry the ore from the crusher. The rolls and screens to be used at this plant are to be installed in the near future, the machinery being nearly all on the ground. The tie preserving plant of the Chicago & Northwestern Railway Co., was next visited. This was of much interest to the members, many of whom had not before seen it in operation.

A very interesting feature was the distribution of a circular by the management, describing the plant, enabling the visitors to read the particulars of its operation before arriving there.

It has been suggested that this plan could be applied in many instances, and add much to the interest of visitors. The circular is here printed in full:

"The plant is operated by the Chicago & Northwestern Railway company for treating ties and other classes of timber for use on its line. Plant occupies about twenty acres of ground for storing untreated and treated ties. Ties are brought in during the winter months and cross-piled sufficiently open to permit circulation of air. Ties should be well seasoned and then peeled before being treated. Ties received during the winter months do not season to any great extent until about April, after which, from 60 to 90 days put the ties in the best condition for treating. Well seasoned ties can be treated more successfully and at a much lower cost than if only partially seasoned. To treat green or unseasoned ties requires prolonged steaming, longer time being necessary to complete the treatment. The fuel used and time required to get unseasoned ties in condition to absorb the preservative add materially to the cost. The yard capacity is about 500,000 ties. A greater number can be taken care of during the year, as the same space can be used for piling as the seasoned ties are treated and forwarded.

"Principal features of the plant are: Three retorts 112 feet long and 6 feet in diameter, and made of $\frac{5}{8}$ -inch steel, with a heavy door at one end; two 100,000 gallon solution tubs, and a suitable system of piping and valves for handling

the solution to and from the retorts. The machinery employed consists of a vacuum pump, air compressor and a pressure pump for each retort. The plant is operated under what is known as the Wellhouse Process. The ingredients used are chloride of zinc, glue and tannin, the chloride being the preservative. The ties are drawn into the retort by means of a system of cables. Thirteen trams constitute a train, average number ties on each tram 28. With the retort doors closed the ties are steamed two and a half hours, with twenty pounds pressure, 260 degrees F. H. to open the pores, after which a vacuum of 22 inches is drawn for one hour to free the pores of sap. The four per cent. solution of chloride of zinc is then allowed to flow from the solution tub into the retort, covering the train, a pressure of 120 pounds is maintained for two and one-half hours, filling the open pores with chloride solution. Absorption having taken place the solution is forced back into the tub and careful readings taken from the tub indicator, before and after the operation, to determine results. The tannin solution is then let into the retort and same pressure applied as before. The glue or tannin being used as a plug for the outer pores to prevent the chloride from leaching out. This completes the treatment. From .4 to a half pound of the pure chloride is put into each cubic foot of timber as a preventative against decay, doubling the life of the tie.

"The plant has a capacity of from 800,000 to 1,000,000 ties per year. The average cost of treatment per tie, including labor, chemicals, fuel and everything necessary for the operation is about 15 cents.

"A force of about 70 men is required to operate the plant."

The train carried the party to the dock where they boarded the steamer Maywood for an excursion around the bay and to Gladstone. Lunch was served on board by the Escanaba committee and was much enjoyed, also saving much time on the trip.

At the docks of the C. Reiss Coal company the first stop was made. The machinery was put in operation for the benefit

of the visitors, there being no boat at the dock at the time. The plant is large and capable of handling an enormous amount of coal.

The next stop was at the hardwood plants of the I. Stevenson company at Wells. There are two saw mills which manufacture 45,000,000 feet of lumber yearly, including 12,000,000 feet of hard maple which is used for matched flooring. The remainder of the output is cedar, basswood, elm and birch, mostly all of which is reduced to dimension lumber. The company owns 220,000 acres, part of which has been cleared. The policy is to clean the lands completely as the work progresses, taking all of the timber and manufacturing it into the various products. The Machek Chemical and Iron company is subsidiary to the I. Stevenson company and uses the material rejected by the saw mills into charcoal, securing as by-products acetate of lime and wood alcohol. The plant has been in operation three years.

At Wells are also the ore and coal docks of the Chicago, Milwaukee & St. Paul railroad. The ore docking capacity is 50,000 tons and 1,500,000 tons can be handled per year. All iron ore handled by the St. Paul is hauled over the Escanaba & Lake Superior railroad from Channing to Wells. This road also is accessible to all of the Stevenson timber lands, and has an aggregate length of 135 miles.

GLADSTONE INDUSTRIES.

The Institute proceeded by the Maywood to Gladstone to view the No. 1 charcoal furnace and by-product plant of the Pioneer Iron company, which is the manufacturing end of the Cleveland-Cliffs Iron company. The furnace manufactures from 110 to 120 tons of pig iron daily. It was only recently placed in blast after an idleness of 17 months and 12 days. Previous to that it had been operated for four years and seven months, at the end of which period the fires were banked. Following the suspension of over 17 months the drafts were opened and the plant was put in blast without rebuilding the fires or removing the charge.

The furnace has a 12-foot bosh, a seven-foot hearth, and is 60 feet high. A blast pressure of six to eight pounds is maintained. The blowing engine compounds the steam, but the high and low pressure cylinders operate entirely independently of each other, although maintaining approximately the same speed, which is 35 revolutions per minute. The air cylinders are each 4x4 feet. These are vertical, while the steam cylinders are horizontal. The jacket water is supplied mostly by four artesian wells, each 600 feet deep.

The waste gases from the blast are used to generate the steam consumed in the engines and also for heating the stoves through which the air passes before entering the blast furnace. Two stoves are employed and the current of air is reversed from one to the other every two hours, one stove being heated while the other is in use.

THE WOOD BY-PRODUCTS.

The Pioneer Iron company manufactures its charcoal at Gladstone for use in its blast furnace by two processes. One is the old fashioned beehive kiln and the other is the modern retort. Both processes yield by-products, but the retort process produces the better results.

The first step in recovering the by-products is to draw the smoke from the kilns and retorts. Four fans are used for this. The smoke is drawn through interminable lengths of copper tubes which are surrounded by cold water, forming an immense condenser, and in this process the smoke is chilled and reduced to a liquid state, which carries a heavy sediment and is coffee colored. This liquid is then put through various processes by which the solids are separated from the fluids and the various by-products are secured.

A cord of wood will produce as a minimum 880 pounds or about 44 bushels of charcoal, eight gallons of wood tar, four and one-fourth gallons of wood alcohol, 208 gallons of pyroliginous acid and 64 pounds of acetate of lime. The charcoal is used in the furnace for reducing the iron ore to pig iron. The acetate of lime is used largely in the manufacture of smokeless

powder. The other by-products have various uses. At the Pioneer furnace the tar is not marketed but is used for fuel, this, together with the waste gases, furnishing practically all the heat required and reducing the coal consumption to a mere nominal figure.

Returning from Gladstone the visitors were conducted to the Ludington and Oliver hotels where banquets had been arranged by the Escanaba committee. The drive planned by the committee had to be given up as a severe rain and wind storm set in shortly after the boat landed at the dock. At nine o'clock special trains left the city for the Marquette and Menominee range towns.

The universal verdict was that this was the most enjoyable meeting yet held. Much is due to the Menominee range and Escanaba committees for this success.

Registry of members and guests in attendance.

REGISTRY OF MEMBERS AND GUESTS IN ATTENDANCE.

AISHTON, R. H.	Chicago, Ills.
AMBERG, J. W.	Chicago, Ills.
ANDERSON, G. A.	Negaunee, Mich.
ANDREWS, C. E.	Escanaba, Mich.
ARMSTRONG, FRANK H.	Vulcan, Mich.
AUSTIN, L. S.	Houghton, Mich.
BANKS, J. A.	Iron Mountain, Mich.
BARBER, MAX. H.	Ishpeming, Mich.
BARBER, G. S.	Bessemer, Mich.
BARROWS, W. A., JR.	Sharpesville, Pa.
BATTU, L.	Chicago, Ills.
BAUDER, W. RALPH.	Ishpeming, Mich.
BAXTER, C. H.	Iron Mountain, Mich.
BENGRY, W. H.	Stambaugh, Mich.
BENNETT, WILLIAM.	Iron Mountain, Mich.
BJORK, ARVID	Crystal Falls, Mich.
BOND, WILLIAM	Vulcan, Mich.
BOYLE, D. F.	Crystal Falls, Mich.

BRENDLER, OTTO	Green Bay, Wis.
BREWSTER, E. E.....	Iron Mountain, Mich.
BRIGHAM, E. D.....	Chicago, Ills.
BRACKETT, A. T.....	Chicago, Ills.
BROUGHTON, H. P.....	Duluth, Minn.
BROWN, E. F.....	Iron Mountain, Mich.
BROWNING, R. C.....	Iron Mountain, Mich.
BUDDLE, J. S.....	Crystal Falls, Mich.
BURR, FLOYD L.....	Vulcan, Mich.
BUSH, JOHN M.....	Ironwood, Mich.
BUZZO, GEORGE.....	Bessemer, Mich.
BYENKA, THOMAS.....	Houghton, Mich.
CAPPIN, J. M.....	Lawrence, Mass.
CARBIS, FRANK.....	Iron Mountain, Mich.
CARNAHAN, A. L.....	Houghton, Mich.
CARPENTER, DR. W. T.....	Iron Mountain, Mich.
CARSON, JOHN A.....	Appleton, Wis.
CHAMBERLIN, H. L.....	Florence, Wis.
CHAMPION, JOHN.....	Loretto, Mich.
CLANCY, JAMES.....	Ishpeming, Mich.
CLEMENS, JOHN.....	Ironwood, Mich.
COLE, W. A.....	Ironwood, Mich.
COLE, C. D.....	Ishpeming, Mich.
CONOVER, A. B.....	Chicago, Ills.
COOK, A. C.....	Iron Mountain, Mich.
COPELAND, FRANK.....	Vulcan, Mich.
COSTLEY, L. M.....	Ashland, Wis.
COVENTRY, F. L.....	Hibbing, Minn.
CRAM, F. W.....	Commonwealth, Wis.
CROWGEY, WILLIAM.....	Bessemer, Mich.
CUNDY, H. J.....	Quinnesec, Mich.
CUNDY, J. H.....	Iron Mountain, Mich.
CUNDY, J. J.....	Quinnesec, Mich.
DAVIDSON, O. C.....	Iron Mountain, Mich.
DEMMERT, H.....	New York, N. Y.
DENTON, F. W.....	Painesdale, Mich.
DICKENSON, E. S.....	Quinnesec, Mich.
DUNBAR, FRANK.....	Marinette, Wis.
DUNCAN, M. M.....	Ishpeming, Mich.
EARLING, H. B.....	Milwaukee, Wis.
EASTMAN, E. C.....	Marinette, Wis.
EDWARDS, J. P.....	Amasa, Mich.
EISELE, GEO. J.....	Iron Mountain, Mich.
ELLARD, H. F.....	Ironwood, Mich.

ERICKSON, JOHN.....	Crystal Falls, Mich.
FAVOR, GEORGE W.....	Chicago, Ills.
FESING, H. W.....	Houghton, Mich.
FEUCHERE, LEON C.....	Ishpeming, Mich.
FISK, FRANK.....	Iron Mountain, Mich.
FITZPATRICK, JOHN.....	Crystal Falls, Mich.
FITZPATRICK, E. D.....	Marinette, Wis.
FLANNIGAN, R. C.....	Norway, Mich.
FLEWELLING, A. L.....	Crystal Falls, Mich.
FLODIN, NELS P.....	Marquette, Mich.
FORMIS, ANDRE.....	Ishpeming, Mich.
FOX, JOHN M.....	Ishpeming, Mich.
FRANQUIST, CAPTAIN.....	Crystal Falls, Mich.
FRASER, W. H.....	Crystal Falls, Mich.
GARNER, W. A.....	Negaunee, Mich.
GENSET, G. F.....	Iron Mountain, Mich.
GIBSON, T. J.....	Amasa, Mich.
GLASS, A. A.....	Detroit, Mich.
GLEASON, FRED.....	Vulcan, Mich.
GOLDSCHRINDT, HERMAN.....	Florence, Wis.
GOLDSWORTHY, JOHN.....	Iron Mountain, Mich.
GOLDSWORTHY, M.....	Iron Mountain, Mich.
GOW, A. M.....	Duluth, Minn.
GRAFF, W. W.....	Ishpeming, Mich.
GREENE, W. E.....	Cleveland, Ohio.
GREER, HOWARD, JR.....	Chicago, Ills.
GRIBBLE, S. J.....	Ironwood, Mich.
GRING, G. W.....	Marquette, Mich.
GULGREN, WALTER.....	Iron River, Mich.
HAIRE, N. W.....	Houghton, Mich.
HAMPTON, C. T.....	Iron Mountain, Mich.
HARDENBURG, L. M.....	Hurley, Wis.
HARRIS, S. T.....	Houghton, Mich.
HARRISON, SAMUEL.....	Peshtigo, Wis.
HASTINGS, E. X.....	Green Bay, Wis.
HEDIN, A. G.....	Ironwood, Mich.
HELLBERG, G. A.....	Norway, Mich.
HELMER, C. E.....	Escanaba, Mich.
HERMANN, OTTO.....	Florence, Wis.
HICKOK, E. E.....	Chicago, Ills.
HILL, HENRY.....	Norway, Mich.
HITCHENS, JOHN H.....	Iron Mountain, Mich.
HODGE, J. E.....	Marquette, Mich.
HOLMAN, J. W.....	Chicago, Ills.

HOPKINS, EDWARD W.....	Commonwealth, Wis.
HUNTOON, HARRY A.....	Ishpeming, Mich.
JACKA, E.....	Crystal Falls, Mich.
JACKA, J. S.....	Crystal Falls, Mich.
JAMES, STEPHEN.....	Iron Mountain, Mich.
JAMES, JOHN.....	Iron Mountain, Mich.
JANSEN, F. A.....	Norway, Mich.
JENSEN, NELS C.....	Commonwealth, Wis.
JETTNER, A. R.....	Chicago, Ills.
JOBE, W. H.....	Stambaugh, Mich.
JOHNSON, CARL.....	Florence, Wis.
JOHNSTON, W. H.....	Ishpeming, Mich.
JOHNSTONE, O. W.....	Ironwood, Mich.
JONES, JOHN T.....	Iron Mountain, Mich.
JONES, A. G.....	Iron Mountain, Mich.
JONES, E. W.....	Iron Mountain, Mich.
JONES, DR. B. W.....	Vulcan, Mich.
JONES, CHARLES C.....	Wakefield, Mich.
JONES, DR. J. D.....	Iron Mountain, Mich.
KARKEET, J. H.....	Iron Mountain, Mich.
KARKEET, RICHARD.....	Commwealth, Wis.
KEEN, HENRY.....	Crystal Falls, Mich.
KEETON, JOHN J.....	Ishpeming, Mich.
KEITH, JOHN M.....	Ishpeming, Mich.
KELLY, WILLIAM.....	Vulcan, Mich.
KING, ROBERT.....	Hurley, Wis.
KINGSFORD, E. G.....	Iron Mountain, Mich.
KIRKPATRICK, W. B.....	Schenectady, N. Y.
KNIGHT, J. B.....	Norway, Mich.
KROAPIL, VOGTA.....	Argonia, Wis.
KRUSE, J. C.....	Iron Mountain, Mich.
KURZ, MAX.....	Iron Mountain, Mich.
LASIER, F. H.....	Detroit, Mich.
LARUE, H.....	Chicago, Ills.
LARSON, EDWARD.....	Florence, Wis.
LAWRENCE, C. E.....	Amasa, Mich.
LATHAM, H. M.....	Worcester, Mass.
LEEDE, E. M.....	Florence, Wis.
LEHANE, JAMES.....	Toronto, Canada.
LESER, THEO.....	Chicago, Ills.
LETZ, J. F.....	Milwaukee, Wis.
LINSLEY, W. B.....	Escanaba, Mich.
LONGYEAR, J. M.....	Marquette, Mich.
LONNERGAN, PIERCE.....	Cleveland, Ohio.

LOOK, F. W.....	Escanaba, Mich.
LORD, E. J.....	Iron Mountain, Mich.
LUXMORE, T. L.....	Iron Mountain, Mich.
LYNCH, T. F.....	Houghton, Mich.
LYNN, ALEXANDER.....	Norway, Mich.
MACE, R. E.....	Duluth, Minn.
MARS, W. P.....	Duluth, Minn.
MACNAUGHTON, JAMES.....	Calumet, Mich.
McDERMOTT, HARRY.....	Iron Mountain, Mich.
McDONALD, D. B.....	Virginia, Minn.
M'GEE, M. B.....	Crystal Falls, Mich.
M'GRAW, I. J.....	Green Bay, Wis.
M'GREGOR, SILAS J.....	Iron Mountain, Mich.
McLAUGHLIN, W. J.....	Iron Mountain, Mich.
McLAUGHLIN, HUGH.....	Iron Mountain, Mich.
McLEAN, J. H.....	Ironwood, Mich.
McNAIR, F. W.....	Houghton, Mich.
MILLAR, J. M.....	Escanaba, Mich.
MILLER, F. H.....	Crystal Falls, Mich.
MILLER, J. T.....	Iron Mountain, Mich.
MILLIMAN, CLAUDE.....	Iron Mountain, Mich.
MILLIMAN, FRANK.....	Iron Mountain, Mich.
MILLS, JOHN.....	Chicago, Ills.
MODER, J. A.....	Calumet, Mich.
MONROE, W. G.....	Iron Mountain, Mich.
MORGAN, D. T.....	Republic, Mich.
NANKERVIS, J. L.....	Calumet, Mich.
NELSON, S. T.....	Chicago, Ills.
NEWETT, GEORGE A.....	Ishpeming, Mich.
NINESS, EDMUND.....	Ironwood, Mich.
O'CALLAHAN, JAMES.....	Norway, Mich.
ODGERS, I.....	Crystal Falls, Mich.
ORRISON, J.....	Houghton, Mich.
ORRISON, T. W.....	Appleton, Wis.
OSWALD, E. J.....	Crystal Falls, Mich.
PASCOE, P. W.....	Republic, Mich.
PASCOE, THOMAS.....	Norway, Mich.
PATBERG, OTTO.....	Florence, Wis.
PEACOCK, D. C.....	Hibbing, Minn.
PEARSON, H. W.....	Duluth, Minn.
PENGILLY, EDWARD.....	Crystal Falls, Mich.
PENTON, J. A.....	Cleveland, Ohio.
PETERSON, JOHN O.....	Winona, Mich.

PHILLIPS, W. G.....	Calumet, Mich.
POWELL, R. S.....	Iron Mountain, Mich.
PRESCOTT, FRED M.....	Milwaukee, Wis.
QUIGLEY, G. J.....	Kaukauna, Wis.
QUINE, J. T.....	Ishpeming, Mich.
RICHARDS, F. W.....	Iron Mountain, Mich.
RICHARDS, W. J.....	Crystal Falls, Mich.
ROBBINS, A. E.....	Iron Mountain, Mich.
ROBERTS, E. S.....	Iron River, Mich.
ROBERTS, F. C.....	Crystal Falls, Mich.
ROUGH, JAMES H.....	Negaunee, Mich.
ROWE, JAMES.....	Iron Belt, Wis.
RUMSEY, S. S.....	Duluth, Minn.
RUNDLE, A. J.....	Iron Mountain, Mich.
RYAN, J. A.....	Iron Mountain, Mich.
SALMONSON, JOHN H.....	Norway, Mich.
SAMPSON, JOHN.....	Ashland, Wis.
SCADDEN, F.....	Crystal Falls, Mich.
SECOMBE, T. H.....	Iron Mountain, Mich.
SEIBERT, GEORGE F.....	Iron Mountain, Mich.
SELLS, MAX.....	Florence, Wis.
SENDERCOCK, E. J.....	Iron Mountain, Mich.
SHEA, J. D.....	Bessemer, Mich.
SHEPARD, A. A.....	Iron Mountain, Mich.
SHERLOCK, THOMAS.....	Escanaba, Mich.
SHOVE, B. W.....	Ironwood, Mich.
SIEBENTHAL, W. A.....	Republic, Mich.
SILLIMAN, A. P.....	Hibbing, Minn.
SLINEY, D. J.....	Ishpeming, Mich.
SOADY, HARRY.....	Iron Mountain, Mich.
SORNBERGER, E. C.....	Buffalo, N. Y.
SPENCER, JOHN T.....	Iron Mountain, Mich.
SPEER, F. W.....	Houghton, Mich.
STANLAKE, JAMES.....	Ironwood, Mich.
STEPHENS, D. A.....	Ironwood, Mich.
STERLING, L. T.....	Iron Mountain, Mich.
STOEKLY, LOUIS.....	Iron Mountain, Mich.
STONE, J. W.....	Marquette, Mich.
SWAIN, R. A.....	Duluth, Minn.
TARR, S. W.....	Duluth, Minn.
THOMPSON, A. W.....	Vulcan, Mich.
TOMS, R. K.....	Ely, Minn.
TREBILCOCK, W.....	Crystal Falls, Mich.

TREPANIER, H.....	Iron Mountain, Mich.
TRUETTNER, I. W.....	Bessemer, Mich.
TUFFTA, J. W.....	Milwaukee, Wis.
TYLER, W. E.....	Chicago, Ills.
VAN VALKENBURG, H. A.....	Abbottsford, Wis.
VAUGHN, S. H.....	Milwaukee, Wis.
VIVIAN, J. D.....	Crystal Falls, Mich.
VOILAND, F.....	Marquette, Mich.
VOGEL, FELIX A.....	Florence, Wis.
WALL, JOHN.....	Crystal Falls, Mich.
WALL, J. S.....	Iron River, Mich.
WALTON, C. E.....	Wakefield, Mich.
WATSON, WILLIAM.....	Iron Mountain, Mich.
WEST, W. J.....	Hibbing, Minn.
WHITEHEAD, ROY G.....	Vulcan, Mich.
WANEGAR, C. T.....	Iron Mountain, Mich.
WOODBIDGE, DWIGHT E.....	Duluth, Minn.
WOODWORTH, GEORGE L.....	Hibbing, Minn.
YOUNG, H. O.....	Ishpeming, Mich.
YOUNGS, FRANK W.....	Iron River, Mich.
YOUNGS, GEORGE C.....	Florence, Wis.
YOUNGS, G. W.....	Iron River, Mich.
YUNGBLUTH, A. J.....	Ishpeming, Mich.

MENOMINEE RANGE.

BY JOHN L. BUELL, QUINNESEC, MICH.

To prepare a communication, which will prove of interest to the members of the Institute, a brief sketch of the early history and successive development of the lower Menominee iron range, while it may be a pleasurable task, is by no means an easy one. To those here who consider only the present and prospective productiveness of the district as a wealth producer, such a paper will be of little interest. With the exceptional references to the mines and operations at the present time, which will only be referred to as illustrative of the remarkable development of wealth and the approved and improved system of mining applied in a section of country, which as late as 1870 was comparatively an unknown wilderness, there will be few statistical or productive allusions. These facts can be more readily and authentically obtained from the annual published reports of the mining commissioner.

It is not generally known that a tradition exists with the Menominee Indians, who were the only habitants of this range prior to the discovery of iron ore; that, if any member of the tribe should disclose to a white man the existence of a mineral deposit, his speedy death was sure to follow in some manner. It is not improbable that this superstition may have, to a degree, influenced the belated discovery and subsequent mining operations on this range; for by bringing specimens, which they could have so readily obtained, to the trading posts, would have incited earlier investigation. Be that as it may, surely it is incomprehensible why, for so many years, the existence of ore deposits in such vast quantity and great wealth should have remained unknown.

Another embarrassment, and one of more substantial im-

port, was the impression, generally heralded, that iron ore of paying quality, and in sufficient quantity, could only exist in the Marquette range. For some unaccountable reason, the geological formation of other districts, where indications of ore were prevalent, not corresponding with those of the Marquette district, precluded the possibility of the existence of paying ore. This impression was general and so effective as to influence the most active and noted explorers, among whom may be included such men as Credner, Pumpelly and Brooks, men of national reputation as geologists, and especially, that branch of geology pertaining to minerals.

Dr. Credner, as state geologist, ventured so far as to publish in his report, the existence of a large deposit of highly silicious iron ore on Section 11, 39-29, and Brooks and Pumpelly, with John Armstrong as guide and woodsman, traversed every section of the lower range, when making the selections of lands for the Canal company. Let it be said in extenuation of Dr. Credner that he was making a superficial geological investigation, studying only outcrops, or surface disclosures, for the purpose of establishing the geological structure of the territory. The other gentlemen, while indefatigable in their selections of the best pine and hardwood lands, were not indifferent to those where mineral indications were favorable. They did no little digging on this and the Metropolitan range, but in no instance did they find any deposits of standard ore. Certainly none which they ever disclosed. The edict had gone forth. "There was no good ore outside of Marquette county," and, burdened with this phantasm, they strolled blindly over locations from which millions of dollars' worth of ore have since been extracted and millions more are yet to come.

It was in the months of October and November, 1858, when the writer journeyed from Leavenworth, Kansas, with a four-wheeled palace car drawn by four yokes of oxen, up the valley of the Arkansas river to Pike's Peak, inspired by a report which came from a small party of adventurers, who had left Lawrence, Kansas, in June preceding, that gold had been found

at the mouth of Cherry Creek, on the head waters of the South Platte river.

It was in the spring of 1859, when a little group of men, disheartened and disappointed, domiciled in log shacks on the present site of Boulder City, witnessed the arrival of long trains of sturdy farmers, from Iowa and Missouri, bound for the Eldorado of their hopes. Misguided men! For they had sold or mortgaged comfortable homes and invested their little all in an outfit which was to secure them future wealth. Up to the date of this influx of deluded immigrants, there had not been mined ten thousands dollars worth of gold in the entire Colorado district. They had simply been misled by the glowing letters of men on the ground, who were fasting on lean deer meat and wild onions, too poor to get away, knowing, full well, that the farmers' wagons would come, well laden with flour and bacon, anxious to exchange for a gold claim, the chief wealth of which consisted of four stakes within which a pit had been sunk and a few scales of gold mingled with the sand.

It was there and then that the memorable epigram, which has passed into history, had its origin. One so characteristic of American energy. One of those farmers, all aglow with the enthusiasm peculiar to gold-seekers, had inscribed upon the side of his wagon in large black letters, the memorable words, "Pike's Peak or Bust." Alas! A few weeks later, the same wagon emerged from the mouth of the canon, homeward bound. One yoke of cattle instead of three. Through the rents in the wagon cover you could catch a glimpse of a haggard-looking woman and three or four hungry and tired looking little ones. The proprietor, with a drooping head and numerous patches on his pants, tramped dejectedly along side of his half-famished steers. Beneath the memorable words, "Pike's Peak or Bust," which had been his talisman through the long tramp up the North Platte valley, he had inscribed the fated, but truthful result of former hopes, "Busted by G!"

And yet, what was this despoiled and disheartened tiller of the soil leaving behind him? A desert? A country devoid

of wealth or of resources? Not so! He was turning his back upon a territory far richer in mineral, in agricultural and grazing resources than the state of Iowa, from whence he came, and to which he was returning.

It was from one of the mountain peaks overlooking to the east, the limitless mesas, the home of the prickly pear, the rattlesnake and the prairie dog, the broad valleys threaded with inexhaustible streams of snow water, that another despondent gold-seeker uttered an exclamation that will go down in history as a truism in its application to Colorado, as well as to all parts of the earth. "I can't believe," said he, "that God didn't make this country for some purpose." And is not this true? It is not yet known that any section of country has been created, that did not in some form or manner become, or is to become, subservient to the ambitions, or avarice, of men. The homesick gold seeker of 1859 and 1860, were he to return to Colorado to-day, would see the mesas and the valleys transformed into productive farms; never crop failing, because of irrigation; its mountain sides the grazing ground of countless herds of cattle and sheep; its gold, silver, coal and iron mines; its smelters and furnaces; its beautiful cities and villages; its railways and highways. Its school houses and churches would lead him to exclaim, "Certainly was this country created for a purpose!"

And so, too, with the iron ranges of this region. No more striking illustration of the rapid development of iron ore in our country, or in the world, is observable than in the rapid opening of the lower Menominee range and the Iron River, Crystal Falls, Gogebic and Minnesota districts, disclosing ore fields over a vast territory, which, a short time previous, if it had appreciable value in the eyes of men, was based solely upon the quantity and quality of the pine timber standing thereon.

The location of this district, remote from water and rail transportation, the reported severity of its climate, as also the reported barrenness of its soil, all tended to divert the immigrants from this section. Saw-logs and saw-mills were the only hymns chanted on the Menominee and its tributaries. The first

seventy-five thousand of pine logs cut on the Menominee, above Lower Quinnesec Falls, was hauled by the New York Lumber company, in the winter of 1870 and 1871, from the little point of land where the outlet of Lake Fumee flows into the main river, Section 3, 39-30. It was an experiment, to determine whether or not, the logs would be of any value after passing over the falls. It was a success; and from that time on the entering of pine lands and lumbering on extended lines on the Upper Menominee and its tributaries were energetically prosecuted.

The first exploring party to enter the territory embracing the lower Menominee range, was Dr. N. P. Hulst, of Milwaukee. As a representative of the Milwaukee Iron Co., he began active exploration with a large force of men on Section 10, 39-29, the summer of 1872. The exploration was not confined to this point, but extended elsewhere along the range, consisting of test-pitting and trenching, with the exception of a long drift across the silicious formation on Section 10.

The writer is not informed as to what success attended Dr. Hulst's researches, but the exploration was discontinued in the fall of that year.

In the fall of 1871, memorable for its devastating fires, which prevailed at Chicago, Peshtigo and other points, the writer, in company with John Armstrong, encamped at the little spring at the north end of Quinnesec avenue, on the present site of the village of Quinnesec. While Armstrong was preparing dinner (it was his turn that day) a little stroll over the bluff to the west disclosed the outcropping of the easterly terminus of the Quinnesec mine formations. This was near the township line on the southeast quarter of Section 34, 40-30. This tract had been entered by Sales & Lasier, with Agricultural Scrip, in 1864, but the entry had been cancelled and the land withdrawn from the market, with all other even sections in this region, to enable the Canal company to complete its selection of 50,000 acres. It was not until the spring of 1873 that the title to this tract was restored to Sales & Lasier, and in

May of that year, exploration was begun by the writer of this paper with a force of fifteen men and prosecuted until a deposit of blue ore was discovered on the 3rd of August, in the same year.

Where the ore was first struck it had a width of eleven feet of clean ore, a jasper horse, four feet in width, and then one foot more of clean ore. Seventy-five feet east the deposit had a width of thirty-three feet. The analysis of this ore gave sixty-six per cent. metallic iron, four per cent. silica and .013 per cent. phosphorus.

In the spring and summer of 1874, fifty-five tons of it was hauled to Menominee on sleds and wagons and smelted in the furnace at that point, with a mixture of Jackson hard ore and Winthrop. The last furnace charge was entirely of the Menominee range ore, thus establishing its tractability. Robert Jackson, superintendent at the furnace, spoke in the highest terms of the quality of the ore. This was practically the first test of standard ore from the Menominee range and was the incentive to rapid and successful exploration along the entire formation.

The following schedule of exploitations and development, which Dr. Hulst has kindly furnished, is given as follows:

Norway mine, discovered by Martin Kilgallon, then station agent of C. & N. W. railway at Vulcan, late in the spring of 1878. A spur track was built into the mine that summer and fall, and some 5,000 tons shipped before navigation for the year ended.

The Cyclops was discovered Oct. 1st, 1878, and Oct. 24th of the same year was shipping 150 tons per day.

Vulcan mine was discovered in 1873 and developed in 1876 and first shipments made in 1877, as soon as the Menominee railroad was completed to it.

The Breen mine was discovered by the Breen Bros., Thos. and Bartley, prior to 1872. Exploration work was continued on it in 1872 and 1873 by the Milwaukee Iron Co., of Milwaukee, Wis. It was operated by the Menominee Mining company

in 1877, and for that year its shipments were 5,812 tons.

The East Vulcan mine was opened up in 1879.

The Quinnesec mine was opened up partly as an open pit in 1877 and first shipments of ore were made in 1878.

The Emmett mine was opened as an open pit in 1877 and during 1878 there were shipped 11,523 tons.

The Cornell mine was discovered in 1879 by John R. Wood. During 1880 it produced 30,856 tons.

The Keel Ridge mine was discovered in 1879 and shipments of 11,445 tons were made in 1880.

The Curry mine was discovered in 1878 and shipments to the extent of 13,010 tons were made in 1879.

The Saginaw mine, later called the Perkins, was owned by the Saginaw Mining company. Capt. Sam Mitchell, of Negau-nee, was principal owner. It was discovered in 1878 and made a shipment of 13,492 tons in 1879.

The Stephenson mine adjoined the Perkins mine on the north. This property was owned and operated by the Lumberman's Mining company, composed of lumbermen, whose lumber mills were at Menominee and Marinette. The mine was discovered in 1878 and shipped 798 tons in 1879. This company also owned and operated the Ludington mine at Iron Mountain. It was discovered in 1879 and in 1880 made a shipment of 8,876 tons.

The Chapin mine was discovered in 1879, in 1880 it made a shipment of 34,556 tons.

The Indiana mine was discovered in 1879. It produced 709 tons in 1880.

The Millie mine was discovered in 1880 and its first season's shipments was in 1881 of 4,352 tons.

To this list should be added subsequent and recent discoveries, the Pewabic, Aragon, Loretto, Munro, Traders, Walpole, Vivian and Cundy. Of the foregoing the Keel Ridge, Cornell, Indiana, Quinnesec, Cyclops, Emmett and Stephenson are apparently worked out and abandoned. The Indiana closed on account of excessive water and the Cundy is temporarily idle.

The Saginaw and the Breen are being reopened, the Hamilton, a recent discovery not mentioned in the above list, and the Ludington have been merged with the Chapin, and the Curry with the West Vulcan. Below is given the estimated product of each mine for the year 1905 and the force at present employed at each location:

Mine.	Product.	Force Employed.
Chapin	972,000	900
Pewabic, Walpole.....	530,000	533
Traders	150,000	80
Vivian	95,000	95
Munro.....	100,000	90
Aragon	430,000	570
Vulcan, E. Vulcan.....	425,000	650
Loretto	94,000	174

Making a total product for the year 1905 of 2,796,000 tons, with an aggregate force of about 3,000 employees.

The product is keeping up, if not exceeding, former years, with the number of employes somewhat reduced, because of the application of improved machinery, underground haulage and improved methods of mining. The quality of the ore produced is not so good as that of former years, yet all of that produced finds a ready market and no complaints are heard from the operating corporations. The scale of wages is as high, if not higher, than ever before on the range. This standard of pay, in the face of reduced value of ore, is only maintained by the use of improved machinery and most skillful management in the raising and shipping of the product.

It is estimated that the ore is now delivered on the cars at some of the mines at a cost 60 per cent. less than in former years. When ore was worth from \$8 to \$12 per ton, the operator could afford to be somewhat indifferent as to the cost of production, but with a price of \$4 at the end of the market, it behooves the management to exercise the utmost economy and skill in the operation of his mine. The Chapin, by far the heaviest producer on the range, has underground electric haulage. It may be of interest at this time to give an extended sketch of this remarkable property, which shows a total product up to Jan. 1st, 1905, (Hamilton and Ludington included) of 13,599,378 gross tons.

The Chapin was discovered in 1879 and made its first shipment, 74,000 tons, in 1880. Since that date, with the exception of 1892 and 1893, it has been a constant and heavy producer. The ore body consisting of a series of lenses extending easterly and westerly 6,100 feet, with a varying width of from fifty to one hundred and fifty feet. The greatest depth yet reached in the mine is 1,460 feet. The standard ore is worked out down to the eleventh level, a distance of 860 feet, yet large bodies of merchantable ore still remain much nearer the surface at both the easterly and westerly termini. The caving process is and has been for some years used in this mine, making the mine much more secure against accidents and permitting the extracting of all the ore at a much less cost than under the old system of mining. The management does not hesitate to assert that under a pressing demand for ore one million tons could be annually raised through the Hamilton shaft alone. The immense body of ore still in sight indicates many years of heavy production in store for this property.

Exploration on this range for the past few years has been quite general, but so far as disclosed with but little success. The diamond drill seems to be the active agent in these researches. The question of formation is a perplexing one. Many different theories are advanced and each explorer seems to have his own. Each and all seem to conclude that when limestone (so-called) is reached that it is useless to prosecute the investigation further. This in the face of the fact that all deposits of the standard blue ore on the ranges are in the direct longitudinal trend of the limestone—in the limestone, not along side of it—all drills pointing to the north and none to the south. I know of no diamond drill which has ever been placed on the range with a view to penetrating the formation immediately north of the lime-rock. They all drill away from it. Never, until the limestone, with a width over all of four miles and a length of from eighteen to twenty, has been thoroughly cut with the drill, can any man say that the lower range has been thoroughly explored. With the immense deposit of ore at the

Pewabic between two beds of limestone, with the Walpole in the midst of it, with the Quinnesec, Norway, Saginaw and Cyclops and portions of the Aragon in the direct trend of an immense deposit of limestone, who will deny the proposition that the new place to look for standard ore is in the limestone and not along side of it?

The corporations engaged in mining on the range at the present date consist of the Oliver Iron Mining company, an adjunct of the U. S. Steel corporation, operating the Chapin, Aragon and Cundy mines, under the management of O. C. Davidson; the Pewabic, operating the Pewabic and Walpole mines, the Mineral Mining company, operating the Breen and Nanaimo mines, both companies under the management of E. F. Brown; the Penn company, under the superintendency of William Kelly, operating the Vulcan properties; the Buffalo & Susquehanna Coal & Iron company, with Capt. McDermott at the head, operating the Munro; the Antoine Ore company, with W. A. Watson as superintendent; Capt. Henry Truscott, superintendent for the Loretto Iron company at the Loretto; Pickands, Mather & Co., with Chas. E. Lawrence as superintendent, operating the Vivian. This, in brief, comprises all the companies engaged in mining operations at the present date on the lower Menominee iron range.

It is in order at this point to touch briefly on another enterprise incidental to the iron ore interest. Within the limit of the range, or accessory to it, are seven great water powers; the two Twin Falls, the Horse Race, the Upper and Lower Quinnesec, Sand Portage and Sturgeon Falls. Four of these at the present date are unoccupied and the immense power at command is going to waste, i. e., the Twins, the Horse Race and Sand Portage. The Upper Quinnesec is and has been for many years occupied by a large compressor plant, the compressed air from which is used for mining purposes by the Chapin mine at Iron Mountain. The Lower Quinnesec, at which there is in operation one of the largest paper and pulp mills in the country, (not incidental to the ore business), the Sturgeon Falls, where

the Penn Iron company has recently begun the construction of an immense electric plant to supply power for the operation of its mines. It is to be expected that the other water privileges named will soon be utilized for manufacturing or other purposes.

Notwithstanding the existence of ore in shipping quantity was fully demonstrated before the expiration of the year 1874, and notwithstanding the heavy demand for lumbering supplies, which at that time were being hauled on wagons from Menominee, it was not until the spring of 1877 that the Menominee River railroad, from its junction with the Northwestern at Powers, was completed to Quinnesec, in 1880 the road was extended to Iron Mountain and thence in successive periods to Iron River, Crystal Falls and the Gogebic ranges. The delay in the construction of the road as far as Quinnesec arose from a matter of doubt on the part of capitalists as to whether this range would sustain a railroad costing exclusive of equipment, \$475,000. The road paid for its construction in its first year of full operation, and this little stretch of railroad from Iron Mountain to Escanaba, since it began operations, has paid for many hundreds of miles of track on the western prairie. We have now three railroads penetrating the range, the Chicago & Northwestern, Chicago, Milwaukee & St. Paul, and the Wisconsin & Michigan. All are doing an ore-carrying business and this with the other traffic incidental to the operation of our mines and the development of a comparatively new country, seems to provide an ample business both in passenger and freight traffic.

It is true that our section is virtually denuded of timber, but the sturdy farmer is rapidly invading the brush and stump land, and green fields, well-filled garner and fatted calves are rapidly assuming the place of the lordly pine so ruthlessly swept away by the unsparing lumberman. With its rich clay loam as a foundation, with abundant streams of living water, salubrious climate and a market hungry for every farm product, the lower range bids fair to become one of the leading agricultural districts of the state.

Another factor in our development is worthy of reference. It is that of good roads. Some two years since the county roads system was adopted in this range. Since this time there have been quite a few miles of the main road through the country graded and rocked and that already finished will compare favorably, if it does not excell, any country highway in the state. Should you gentlemen, during your visit, be afforded the opportunity, as you possibly will, of riding over it, you can take lessons from its efficient spirit, William Kelly, who is supervising the work.

This, gentlemen, concludes the tax upon your patience, but before a final closing, reference is in order to some of the by-products of this range—products more useful than ornamental, and yet highly ornamental. Attention is called to a few of the young men who came to this range of an early date and in minor positions linked their destiny with its mining progress. We are proud of them, proud of their positions and prosperity, proud to think that the range can claim them, with all the enviable reputation they have acquired as practical miners—can claim them as some of its most complimentary productions. Among these we find the names of Hulst, Cole, Davidson, MacNaughton, Jones, Brown, McLean and many others. Their hair is beginning to ripen, the sight dimming somewhat, but the purpose of their lives is still before them for a worthy and successful completion.

The list of absentees of those who were identified with the early development of the lower range is a large one. It includes the names of Conro, Brown, both of the Kimberlys, Foster, Williams, Stockbridge, Ludington, Stephenson, VanSchaik, Wells, Ingalls, both of the Olivers, Rundle, Bartley Breen and others not now occurring to memory. All these have crossed the dark river, and others are trimming their sails for the fateful voyage.

THE UTILIZATION OF EXHAUST STEAM FROM
ROLLING MILL ENGINES, HOISTING ENGINES,
STEAM HAMMERS, ETC., BY MEANS OF
STEAM REGENERATORS AND LOW-
PRESSURE TURBINES ON THE
RATEAU SYSTEM.

BY MR. L. BATTU, CHICAGO, ILL.

Owing to various well-known technical difficulties intermittent running engines, such as those used in mines and steel works, have not advanced in the economy of steam to the same extent as have continuous running engines, and even when superheating and central condensing systems are applied, the consumption of steam in the former type of engine is far greater than in the latter.

Reversible rolling mills and hoisting engines generally exhaust direct to atmosphere and the consumption per H. P. is very high. The average consumption of cogging mill engines, making allowance for stops, is about 20,000 to 30,000 pounds per hour; the consumption of engines driving finishing trains varies from 35,000 pounds for rail and merchant mills, to 50,000 pounds and sometimes a great deal more for large plate mills.

From definite tests we know that the great number of hoisting engines non-condensing consume at least 80 to 100 pounds per effective H. P. hour in mineral hoisted.

As illustration, if we assume that the engines in a mine or in steel works use 32,000 pounds of steam per hour and that this steam is expanded from atmospheric pressure to a vacuum of say 26 inches, according to Rankine's formula, this quantity of steam would be capable of developing theoretically in the neighborhood of 1,800 H. P.

Hoisting engines of moderate size consume large quantities of steam. The nature of their work itself shows plainly that the best type of engine cannot have a low steam consumption per useful H. P. as compared to an engine where the load is practically constant. The problem of utilizing the enormous quantity of heat thus going to waste involved two vital questions:

First. What motor could utilize to advantage pressures in the neighborhood of one atmosphere absolute?

Second. Is it possible to obtain a constant flow of steam with slight variations in pressure from the exhaust of engines working with starts and stops, without interfering with the running of the main engine?

The first question is no great problem as it is well-known that the efficiency of low-pressure turbines is very high.

The second question has been solved by Dr. Rateau, professor in the School of Mines of Paris, by his steam regenerator.

THE NATURE AND FUNCTIONS OF THE REGENERATIVE STEAM ACCUMULATOR.

The possibility of utilizing the exhaust steam from continuous-running reciprocating engines in a turbine presents no difficulties. The difficulty of application, however, to engines whose exhaust is irregularly intermittent whilst the turbine requires a continuous supply of steam, has been overcome in the following manner. The principle upon which the apparatus is based involves the application of the properties possessed by saturated steam and saturated liquids respectively when brought together, and of the heat exchanges which take place between the steam and water, either directly or through the medium of metallic surfaces. Under any specified conditions of pressure and temperature these two fluids-saturated steam and steam-saturated-water composed as they are of similar molecules, preserve a reciprocal condition of equilibrium; so that any variation of this equilibrium determines the transfor-

mation of either form of fluid into the other form, with a corresponding absorption of heat in one case or liberation of heat in the other.

This property being granted, if the intermittent exhaust steam is conducted to a receiver containing cast iron and water, the cast iron will absorb heat, and cause upon its surface the condensation of a certain quantity of steam, which remains in the state of steam-saturated water. Owing to this condensation, heat accumulates whenever an abundant supply of steam arrives in the accumulator and causes an elevation of temperature, and such steam as is not condensed causes a slight rise in pressure. This rise of pressure is adjustable, and is only relative, as all these functions may, if necessary, be carried out at or below atmospheric pressure.

When the supply of exhaust steam ceases, the steady demand of the turbine reduces the pressure and provides the necessary disturbance of heat equilibrium. The latent heat of the steam held in reserve by the cast iron and the water serves to vaporize a given weight of water, and the flow of steam to the turbine is thus maintained absolutely constant.

These exchanges of heat take place with extreme rapidity, and the necessary fluctuations of temperature and pressure can be exactly regulated by the design of the accumulator and the regulation of the relief valve.

This, then, is the principle of the Rateau regenerative accumulator. Its action can best be compared to that of the fly-wheel of an engine. The mass of the fly-wheel stores excess energy and gives it out when required; the mass of the accumulator stores heat and gives it off in the form of steam when the turbine requires it.

The weight of material necessary for the regeneration increases in proportion to the quantity of steam to be regenerated per hour and the duration of periods of stop of the rolling mill or other engines.

CALCULATION OF THE DIMENSIONS OF AN ACCUMULATOR.

The weight of materials necessary to the regeneration of

steam increases in proportion to the quantity of steam per hour and the duration of the stops. Suppose, for instance, it is desired to construct an accumulator where water only is employed as a heat retaining body. During each stoppage of the primary engine the accumulator must give up a steam equal to

$$P = \frac{Qt}{3600}$$

Q being the weight of steam per hour and t the duration of each stoppage expressed in seconds.

These P pounds of steam contain at atmospheric pressure 966 B. T. U. per pound. Whence the accumulator must be figured to be capable of giving up $P \times 966 = N$. B. T. U. within the allowable limits of variation of pressure.

Calling Z the variation of pressure corresponding to these pressure limits existing between the commencement and end of each period of rest, and if x be the required weight of water forming the "heat fly-wheel," we have (the specific heat of water being unity).

$$x = \frac{N}{Z} = 966 \frac{P}{Z}$$

If, in place of water, the "heat fly-wheel" is composed of cast-iron, of which the specific heat is about 0.11, a mass of iron will be required nine times as great as we have obtained above. For example, the steam consumption of the secondary engine being 2,200 pounds per hour (corresponding to about 77 effective horse-power), the duration of each stop being one minute (or 60 seconds) and the allowable range of temperature 10 degrees F., then we have

$$P = \frac{2200 \times 60}{3600} = 36.6$$

and the accumulator must deliver

$$36.6 \times 966 = 35,400 \text{ B. T. U.}$$

Whence, the weight of water necessary to deliver this quantity

of heat per minute, with a range of temperature of 10 degrees F., is

$$\frac{55400}{10} = 3540 \text{ pounds, or about 1.5 tons.}$$

$$\text{For cast-iron, a weight of } \frac{1.5}{0.11} = 13.75 \text{ tons, is required.}$$

MIXED REGENERATOR WITH C. I. TRAYS CONTAINING WATER.

This type of accumulator has been in use at the Bruay, mines, in the Pas de Calais, since, Augsut, 1902. The accumulator consists of one or more cylindrical vessels of sheet steel, placed vertically or horizontally, and inclosing a number of C. I. trays filled with water. (Fig. 1.)

The steam enters at the top, and is distributed over the trays by the central passage, a portion passing straight through to the outlet goes to the turbine. The steam passing down the center passage is baffled by the plate at the bottom and forced to pass between the trays, spaces being formed by distance pieces cast on the trays. The steam that is regenerated passes out at the outlet shown near the bottom of the vessel, and passes to another similar accumulator, which is connected to the pipe leading to the turbine.

An oil-separating chamber is formed at the top of the first vessel; and should any oil pass, there is little probability of its settling on the surface of the cast iron, owing to the brushing action of the steam.

The accumulator is fitted with relief and automatic drain valves.

SIMPLE WATER ACCUMULATOR.

In this type of accumulator the mass consists of water only. The economy in first cost is important, as water costs nothing. Water, however, is a bad conductor; and the difficulty to be faced is to obtain a sufficiently rapid interchange of heat between the water and the exhaust steam. This difficulty has been overcome by causing violent circulation in the center of the liquid, so as to increase the amount of contact between

steam and water particles.

The accumulator (Fig. 2) consists of one or more horizontal cylindrical bodies of wrought-steel plate, in the interior of which are arranged a number of elliptical tubes, AA, which extend from end to end of the vessel, and are so placed as to leave spaces between them. There are, as a rule, four to six tubes, in pairs; and the adjacent sides of each pair are pierced with a number of small holes. Baffle plates are arranged above the space between each pair of tubes.

The steam enters by the pipe shown at left hand of side elevation, through the non-return valve, and passes to the interior of the elliptical tubes, and escapes into the spaces through the perforations. The circulation of the water takes place in the direction of the arrows; the baffle plates placed above each pair of tubes prevent the water from being thrown into the steam space. This flow of steam gives an extreme degree of steam saturation to the water; and the slight back pressure which at first sight might be expected, owing to the head of water above the rows of perforations, is thereby reduced to insignificant proportions.

When the supply of steam from main engine ceases, the water liberates the latent heat it has absorbed, and an even flow of low-pressure steam is given off, whilst the steady demand of the turbine reduces the pressure in the accumulator, causing the steam still retained in the tubes to escape, maintaining the circulation of the water, and facilitating the liberation of the steam. Experience has shown that the whole of the contained water participates in the regenerative action. The steam is taken from the top of the accumulator to the turbine, and the pressure can be regulated by the relief valve shown. The water-level is maintained constant by a ball-float contained in a small tank arranged at the back of the regenerator.

ACCESSORIES.

The accumulators are fitted with the following accessories:

Adjustable Relief Valve.—This valve is fitted to regulate

the limits of pressure in the accumulator, and to allow the steam to escape when the turbine is stopped or working on a light load. It also ensures the absence of undue back pressure in the cylinders of main engines. This valve may be connected to the condenser so that if the turbine is standing the main engines may have the benefit of the vacuum, and in cases where surface condensers are installed, pure hot water will be saved for use in boilers.

Non-Return Water Valve.—This valve is generally necessary with water accumulators, to prevent any possibility of reflux of water towards main engines during long periods of stoppage. It is placed in a by-pass connecting the steam reservoir of the regenerator and the exhaust pipe of main engine.

Automatic Level Regulators and gauge glasses are fitted to water accumulators, and automatic drains to mixed or scrap type accumulators.

LOW-PRESSURE SECONDARY MACHINES.

The constant current of steam coming from the accumulator goes to feed a low-pressure motor. This could, theoretically, be a piston machine; but the steam pressure being that of the atmosphere the cylinders and ports would have to be of such enormous dimensions to handle the necessary volumes of steam, that the efficiency would be very low; and, moreover, its size and weight would render the costs of installation prohibitory.

Further, the net power of such an engine would be very much lower than that obtainable from a turbine, owing to the greater friction load, but chiefly on account of excessive condensation; these losses in reciprocating engines being greatest when initial pressures are low and condensing is resorted to on account of the great drop in temperature of steam at low pressure for very small drops of pressure. Thus, steam at 120 lbs. absolute has temperature of 341 degrees Fah., and steam at 15 lbs. absolute has temperature of 213 degrees Fah. There is therefore for a fall of 105 lbs. pressure a fall in temperature

of 128 degrees Fah., or a mean of 1.2 degrees Fah., for every pound of pressure.

When dealing with low pressure, however, we have very much greater drops in temperature per pound of drop pressure. Steam at 15 lbs. absolute has a temperature of 213 degrees Fah.; steam at 2 lbs. absolute has a temperature of 126.3 degrees Fah. Thus, for a difference of 13 lbs. in pressure, the fall is 86.7 degrees Fah., or a mean of 6.7 degrees Fah. per pound drop in pressure, i. e., over five times that in the case of steam expanding from 120 lbs. to 15 lbs. absolute.

The difficulty of internal condensation is almost entirely removed by using a steam turbine, as there are no fluctuations of temperature between limits of initial and exhaust pressures. Moreover, the high speed of steam at these low pressures can be fully turned to account.

Professor Rateau, in addition to having attained remarkable results with high-pressure turbines, has devoted much time and study to the question of turbines for use with the lowest ranges of pressure, with the result that in his multicellular type of low-pressure turbine he has obtained efficiencies of from 65 to 70 per cent. of the theoretically perfect engine.

The Rateau turbine is now so universally known that a description of it need not be given, especially as the designer has himself so lucidly set out the principal advantages of his remarkable system in a number of communications. These turbines having an important bearing on our subject, I will recall briefly the special advantages they present for the rational use of exhaust steam.

COMPOUND TURBINE SYSTEMS.

Under certain conditions of working in steel works, and more particularly in mines, the main engines stop working for longer periods than the accumulators have been designed to accommodate. In order to render the turbine independent of the main engines, the low-pressure inlet valve is fitted with specially-designed reducing valve, so regulated that when the

pressure in the accumulator falls below a predetermined and adjustable point, live steam at reduced pressure is admitted. Owing to the considerable degree of superheat caused by expanding steam of boiler pressure by wire-drawing in a reducing valve to atmospheric pressure, the consumption of the turbine when working with high-pressure expanded steam is lower than when working with exhaust steam. For instance, a turbine using 35 lbs. of exhaust steam per E. H. P. working with a vacuum of 25 in., will only use 22 lbs. of steam when using boiler steam expanded in reducing valve to atmospheric pressure.

This result is usually good enough for steel works working day and night shifts, as the periods of abnormal stoppage of main engines, necessitating use of live steam, are not frequent; the demand for power also falling off greatly when the mills are stopped.

In the case of mines, however, when the hoisting engines are only working 10 hours per day, and the full power of the turbo-generators may be required throughout the 24 hours for pumping, air compressing, etc., a demand has arisen for more economical working under live steam.

Professor Rateau, therefore, devised the system of supplementing the low-pressure turbine with a high-pressure turbine which revolves idly whilst the main engines are exhausting to accumulator, but which is automatically fed with high-pressure steam at the moment the pressure in the accumulator falls below a predetermined point. This high-pressure turbine exhausts to the low-pressure turbine in the ordinary way. Such a group is shown in Fig. 3, and must be regarded as a high-pressure turbine system using under the most economical conditions either high-pressure boiler steam or exhaust steam from the accumulator system. With a good vacuum this group only requires from 15 to 17.6 lbs. of live steam per E. H. P. hour, and from 26.5 to 36.5 lbs. of regenerated exhaust steam, depending on the degree of vacuum obtained.

Should the amount of power required exceed that obtain-

able from the exhaust steam available, a combination of high-pressure and low-pressure turbines, as described above, would be the cheapest and most satisfactory method of working.

The group of turbines illustrated in Fig. 3, was arranged to work under an extraordinary series of combinations, and the design required the greatest care. The plant is working at the Reunion Mines of the Madrid Saragossa Alicante Railway Co., in Spain, and comprises two groups of 350 E. H. P., each of which can be supplied either simultaneously or separately with low-pressure exhaust steam, or with steam coming from one group of boilers at 71 lbs. per square inch, or from another group of 170 lbs. per square inch.

In small plants the high-pressure and low-pressure turbines are combined in one shell.

ADVANTAGES OF THE RATEAU SYSTEM COMPARED WITH CENTRAL CONDENSING PLANTS SHOWING THE EXTRA EFFICIENCY OBTAINED BY THE INTERPOSITION OF THE ACCUMULATOR SYSTEM.

In cases where central condensing plant already exists, the saving in costs effected is still very great even when allowance has been made for loss of benefit of vacuum in the cylinders of main engine. It must be noted, however, that in cases where the main engines are overloaded and require a total absence of back pressure or even a slight vacuum, it is possible to work with a partial vacuum at the turbine inlet, as will be seen from Table I., with an inlet pressure of only 7.1 lbs. absolute, the consumption of steam per electric H. P. is only 36.4 lbs. Of course this arrangement reduces the power recoverable and should not be used unless circumstances necessitate its adoption.

TABLE I.

		Pressure at Admission lbs. absolute per sq. in.			
Vacuum at Outlet of Turbine.....	29.4	14.7	7.1	
 inch.				
Surface Condenser	27.5	20.5	26.5	36.4	Consumption per electric H. P. hour.
Jet Condenser	26	23.6	31.8	47.5	
Ejecto Condenser	24.6	26.5	36.4	61.8	

The saving effected by interposing the accumulator and turbine between the main engine and the condenser is due to the fact that the turbine carries the expansion of the steam to its extreme limit whilst doing useful work whereas the great amount of heat contained is given us uselessly if the condenser only is fitted. Calculations show clearly the justification of the foregoing claim.

Suppose for example that the average consumption of the engines exhausting to atmosphere is 32,000 lbs. per hour, we can determine the benefits arising

- (1) From the application of condensation only;
- (2) From the application of accumulator, turbine and condenser.

(1) Condensing under the best conditions corresponds to a saving of 15 to 20 per cent., this figure being impossible to attain under the running conditions of hoists, however for purposes of demonstration we will take the latter figure; 20 per cent. of 32,000 corresponds to 6,400 lbs. of steam saved per hour. Now if this steam be used in a high class piston engine driving a dynamo and consuming, say, 16 lbs. of steam per hour, we have a theoretical gain of 400 H. P. made by condensing. I say "theoretical" advisedly because it has been the experience of several steel works' and mines managers that the addition of condensers to their main engines has not reduced either number of boilers required to steam their engines or their annual fuel expenses.

Now suppose the whole of the 32,000 lbs. of steam on its way to the condenser be passed through a Rateau accumulator and turbine, assuming that the vacuum is about 27 allowing 20 per cent., for condensation in engine cylinders, pipes, etc., we have 25,600 lbs. of steam available and with a consumption per E. H. P. of 30 lbs. a total of 850 E. H. P. is recoverable or more than double the benefit obtained by the use of condensing plant only.

If it is desired to benefit the rolling mill or other engine by

a certain degree of vacuum, there is nothing to prevent the feeding of the turbine with steam at a pressure below that of the atmosphere.

Table I shows the actual consumption of steam which has been observed on three different installations under actual working conditions.

The second column of consumption refers to the normal case in which the turbine works at atmospheric pressure.

The first, to the case in which with the object of increasing to the utmost the advantage of the turbine the pressure of the exhaust steam has been raised to 29.4 lbs. absolute; and the third corresponds to the employment by the turbine of an exhaust pressure of only half the atmospheric pressure, or, in other words, the turbine works with a vacuum of about 14 inches of mercury at the inlet.

It may happen in a plant consisting of reciprocating intermittent working engines with an accumulator turbine system and a central condenser, that the turbo generator will work during a portion of the day on a reduced load.

It is only necessary in this case—the relief valve on the accumulator being adjustable and connected to the condenser—to reduce the resistance of the spring to establish a lower pressure, say, 7.3 lbs. absolute throughout the system.

The main engines will thus derive a larger proportion of benefit from condensation, and still the required amount of power will be furnished by the turbine.

If there be no objection to increasing the back pressure in the main engine cylinders, even greater advantages accrue. Take, for example, an engine consuming with free exhaust 32,000 lbs. of steam per hour at, say, 100 lbs. per H. P. hour; assume also the absolute steam pressure to be 71 lbs. per square inch at admission.

If exhaust takes place at atmospheric pressure, the consumption of the attached turbine will be 31 lbs. per electric H. P. hour. The 32,000 lbs. of steam used reduced by con-

densation to 25,600 lbs. will then furnish the plant with a supplement of power of

$$\frac{25600}{31} = 826 \text{ electric H. P.}$$

or a total with the primary engine of 1,145 H. P., which makes the consumption per effective H. P. about 28 lbs.

Suppose the pressure of exhaust be now raised to 30 lbs. absolute, the steam will have to be admitted at a pressure of at least 90 lbs. per square inch absolute, instead of 71, and the area of inlet increased by about 25 per cent. in order that the main engine shall develop the same power. The consumption will then become approximately:

$$32000 \times \frac{90}{71} \times 1.25 = 54436.$$

The turbine will, therefore, receive, making allowance for 20 per cent condensation, $8 \times 54436 = 43548$ lbs. of steam per hour at 30 lbs. absolute per square inch.

With this inlet pressure, the turbine consumption will fall to about 22 lbs. per E. H. P. hour.

The extra power afforded will, therefore, be:

$$\frac{43548}{22} \times 1979 \text{ electric H. P.}$$

The 54436 lbs. of steam would thus yield, including the main engine, a total of 2,299 effective H. P. which corresponds to a steam consumption over the whole system including main engine, accumulator and turbine, of 23.5 lbs. per H. P. hour instead of 28 in the case of exhaust at 14.7 absolute.

SAVING EFFECTED.

The economy resulting from the application of the Rateau Plant can be ranged under two heads:

(1) SAVING IN THE COST OF INSTALLATION.

If the installation costs of a turbo generating plant with accumulator are compared with that of an electric plant with reciprocating engine and boilers, there is a marked saving in favor of the former. This arises from the fact that the accumulator regenerator is substituted for costly steam boilers and

settings, flues and sometimes chimneys. The turbo generator also is, as a rule, cheaper in first cost, and when foundations and buildings are added in each case, the saving becomes much greater as the turbo generators require practically speaking no foundations.

The relative importance of these various elements vary, naturally, according to the condition under which the main engine works and of local conditions as to water supply for circulating in condenser, etc.

The great variation in cost of engines and generators depending on type adopted, also renders the giving of exact figures impossible, the question requiring special calculation for each case.

(2) REDUCED OPERATING COST.

These savings result principally from the fact that no additional coal is burned while the primary engine is in operation, and also because, there being no additional boilers required, there are no maintenance, interest and depreciation charges on them.

As an illustration, a 500 E. H. P. operating 20 hours a day, 300 days per annum, will realize the following economies:

1. Saving of coal, 6,000 hours (coal at \$2.00 a ton) . \$9,000
2. Two firemen at \$2.00 per day 1,200
3. Less fixed charges, say at 10% 1,200

Making an annual saving of \$11,400

No boiler maintenance is also an important feature.

ADVANTAGES OF THE SYSTEM.

Easy to install; takes up very little space, and costs much less than a reciprocating engine installation of the same power.

No attendance nor repairs on the steam accumulator.

The energy recovered by means of the turbines can be used for driving dynamos, centrifugal pumps, and fans of low or high pressure, all extremely simple apparatus and easily taken care of.

Great economy in operation. No coal or additional boilers required.

The arrangement of the bearings outside the turbine prevents all oil reaching the condenser.

Possibility of employing combined high and low-pressure turbines, so that the steam, whether high-pressure or low-pressure, is always utilized to the best advantage.

Generally a rational and more perfect utilization of the heat energy contained in the steam.

APPLICATION OF RATEAU PLANTS IN OPERATION OR UNDER CONSTRUCTION.

The first plant was installed at No. 5 pit of the Bruay Collieries, Pas de Calais, and since August, 1902, has worked continuously and has given very satisfactory results. The plant is shown in Fig 5. The exhaust steam of a winding engine, regulated by a mixed cast-iron and water accumulator, feeds a low-pressure turbine of 300 H. P. coupled to two continuous current generators. It may be of interest to state that since the plant was first installed it has required no repairs and the turbine casing has never been opened. Table II gives a list of observations taken under working conditions:

TABLE II.—OBSERVATIONS ON 300 H. P. TURBO-DYNAMO.

RPM.	Volts.	Amps.	Kilowatts at Terminals.	Electric H.P.S. at Terminals.	Temperature of Steam Degr. Cent.	Absolute Pressure		Steam consumption	*Effic. of Turbine and Dynamos Together.
						on Entering lbs. per	on Issuing sq. in.	per E.H.P. per hour, lbs.	
1690	495.	385.	190.5	259.	132	12.	2.2	39.5	0.559
1830	50.	392.	197.5	268.5	132	12.	2.2	38	0.578
1840	503.	393.	198.	269.	133	12.	2.2	38.	0.581
1700	510.	472.	240.5	327.	135	14.	2.56	28.5	0.559
1800	515.	480.	247.	336.	135	14.	2.51	37.	0.580
1591	505.6	399.6	202.	275.	137	12.8	2.318	39.5	0.531
1598	503.2	462.1	232.5	316.5	147	14.28	2.787	39	0.556

* The overall efficiency corresponds to the ratio of the electric H. P. measured at the dynamo terminals, to the energy theoretically contained in the steam consumed if used in a theoretically perfect engine.

Mines de la Reunion, Spain.—Accumulator of old rails (Fig. 3); two 220 K. W., high and low-pressure turbines condenser, (Rateau "Ejecto" type.)

Mines de Bethune, Pas de Calais.—Water-type accumulator; high and low-pressure turbo-compressor compressing 2,100 cubic feet of free air per minute to 85 lbs. per square inch.

Donetz Steel Works, Russia.—Mixed cast-iron and water accumulator in two bodies; six turbo-generators 350 H. P. each, total of 2,100 H. P. continuous current.

Poensgen Steel Works, Dusseldorf.—The installation at the Poensgen Steel Works utilizes a central condensing plant already existing. The steam regenerator is of the pig-iron tray type. The weight of cast-iron is 120 tons. This regenerator receives the steam from several engines, namely, a reversible rolling mill and several power hammers. The total steam consumption of those engines is 22,000 pounds approximately. The variations in pressure in the steam regenerator are less than $\frac{3}{4}$ of a pound per square inch. A test of three days has shown that the condensation which could take place in the steam regenerator was practically null. This steam regenerator is thoroughly protected against radiation losses by a lagging of insulating material. The low-pressure turbine drives a direct-current dynamo at 1,400 R. P. M.; the vacuum in the condenser is 26 inches. The normal load of the set is 650 E. H. P. The current produced thereby is utilized for lighting purposes and for driving a rolling mill. Figs. 5 and 6, shows the regenerator and turbo-generator.

Mines de Firminy, Loire.—The installation of Roche-la-Moliere is equipped with a regenerator containing 25 tons of water and receives the exhaust of a hoisting engine. The total amount of steam consumed per hour is 9,000 pounds. The trips of the cages are of about two minutes with stoppages of $1\frac{1}{2}$ minutes.

The variations of pressure in the steam regenerator are less than 1.42 pounds per square inch, although the stoppages sometimes last as long as two minutes, which is a very long

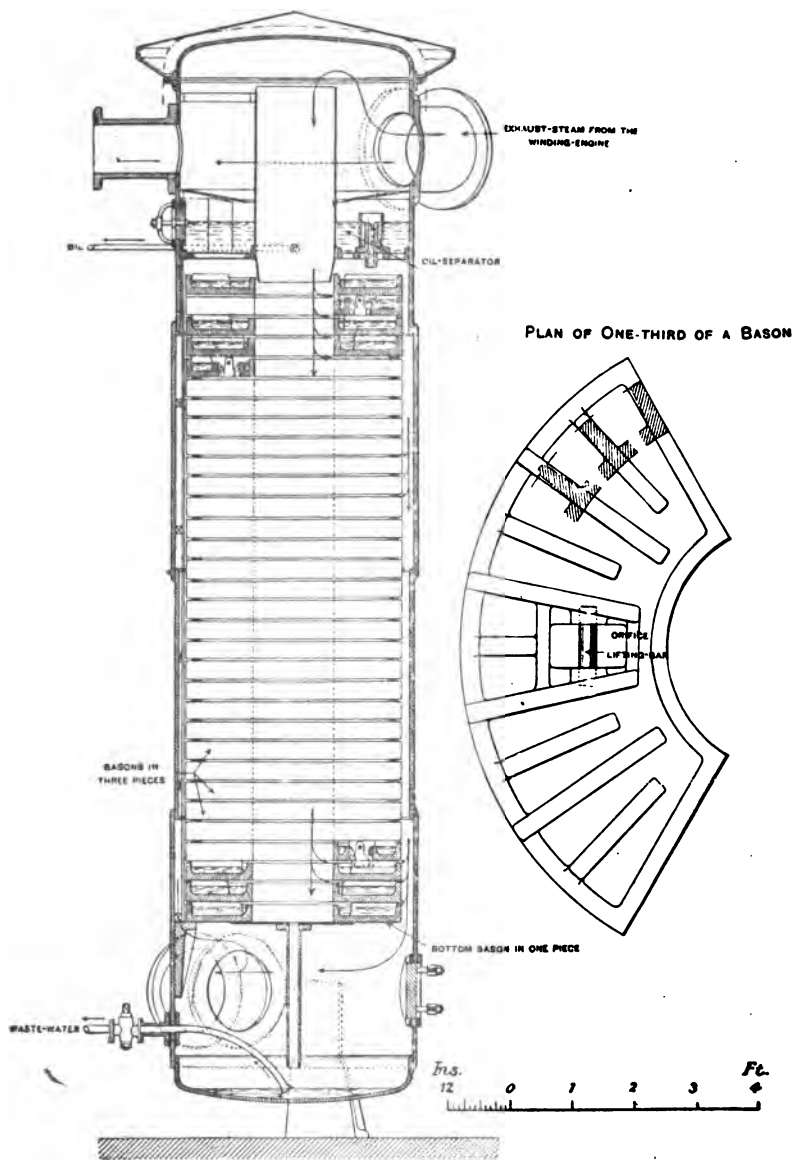


Fig. 1.

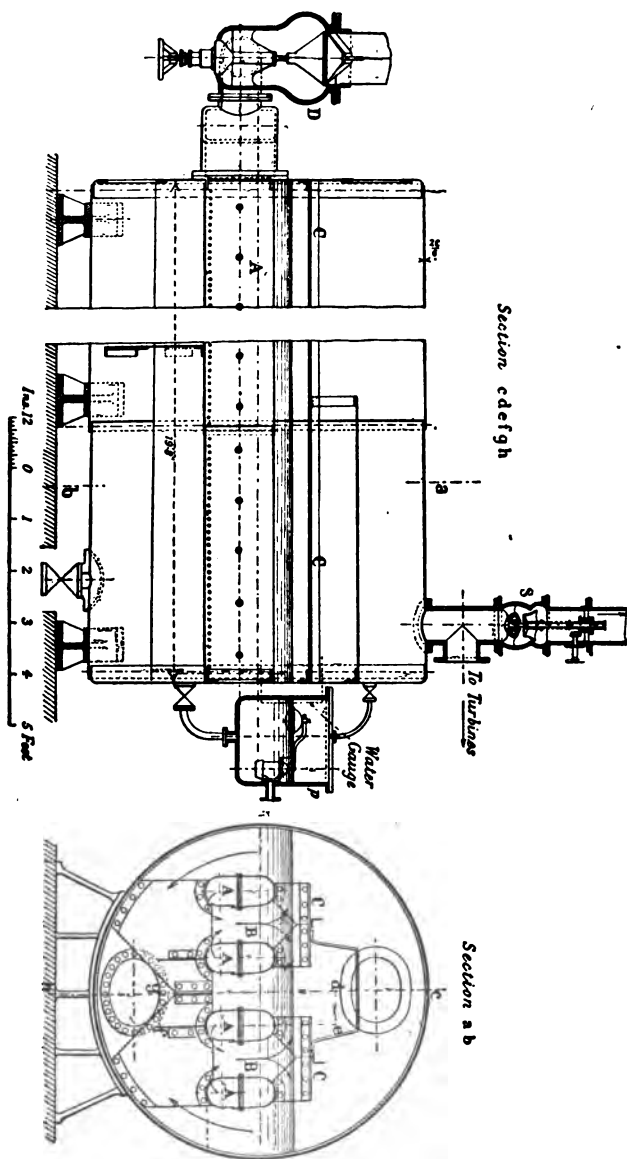


Fig. II.

period for colliery hoisting engines. Special tests have been made which have shown that the steam comes out very dry when admitted to the turbine. The escape valve of the regenerator did not exhaust although the tests were made during several hours when running under normal conditions.

In order to know the exact value of radiation, the steam was not admitted in the steam regenerator for 17 hours (from 3:30 p. m. to 8:30 a. m.) The temperature of the water fell only 40°F. The losses of heat in the regenerator by radiation and conductivity were then 35,000 calories per hour which corresponds, while in running condition, to a loss of 130 pounds of steam per hour. The regenerator was not then covered with insulating material and was not sheltered, the temperature being only 48°F.

The turbo dynamo of the Rateau type drives a three-phase alternator rated at 250 E. H. P., speed of rotation 1,800 R. P. M. The steam consumption of this engine, working between 14.7 pounds absolute and a vacuum of 27 inches, is 28.5 pounds of steam per E. H. P., measured at the terminals. It can be seen that this small machine has an efficiency of 60% for the set—turbine and dynamo. The power produced is utilized to drive the motors of the condenser and also to drive two centrifugal pumps located in the mine itself. These pumps are of the Rateau type having a total lift of 410 feet and 720 feet respectively, the output being 26,300 gallons and 15,800 gallons per hour respectively.

Mines de Hibernia, Westphalia.—Water accumulator; turbo-alternator 365 K. W. exhausting to existing central condenser.

Rombach Steel Works, Rombach.—Water accumulator; two turbo-generators of 500 K. W. each exhausting to existing central condenser.

Gelsenkirchener Bergwerks (Mine of Alma) Germany.—A. C. current, 600 H. P.

Dusseldorfer Rohren, Germany.—700 H. P., D. C. current.

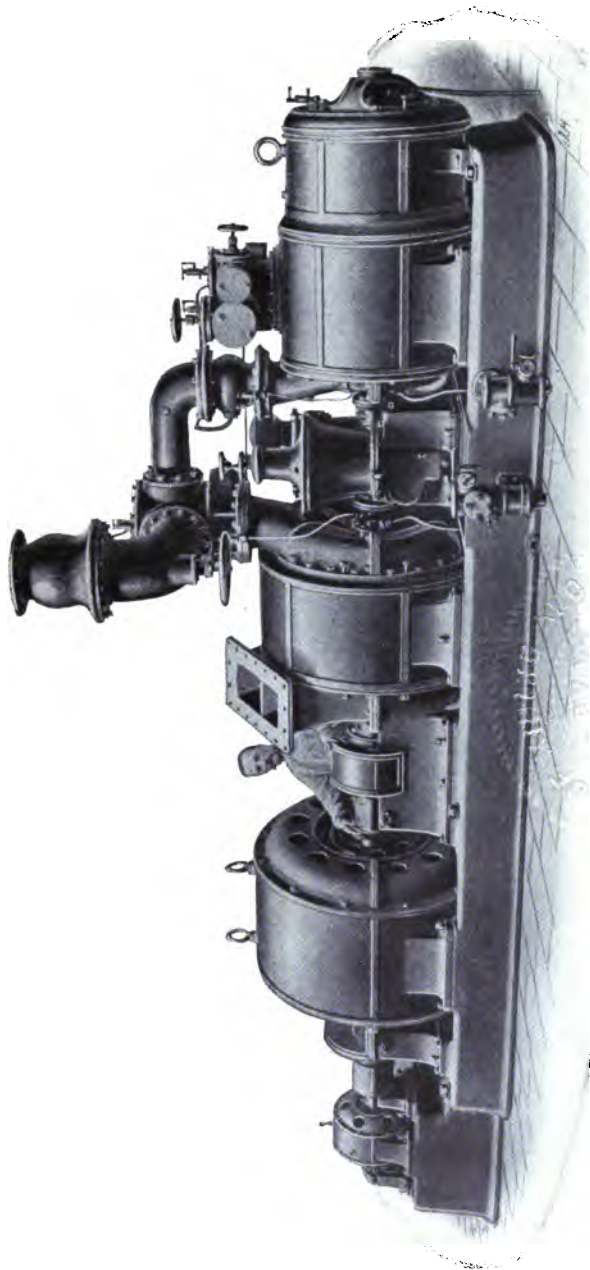


Fig. III.
350 H. P. MIXED HIGH AND LOW PRESSURE RATEAU, DRIVING ALTERNATOR.

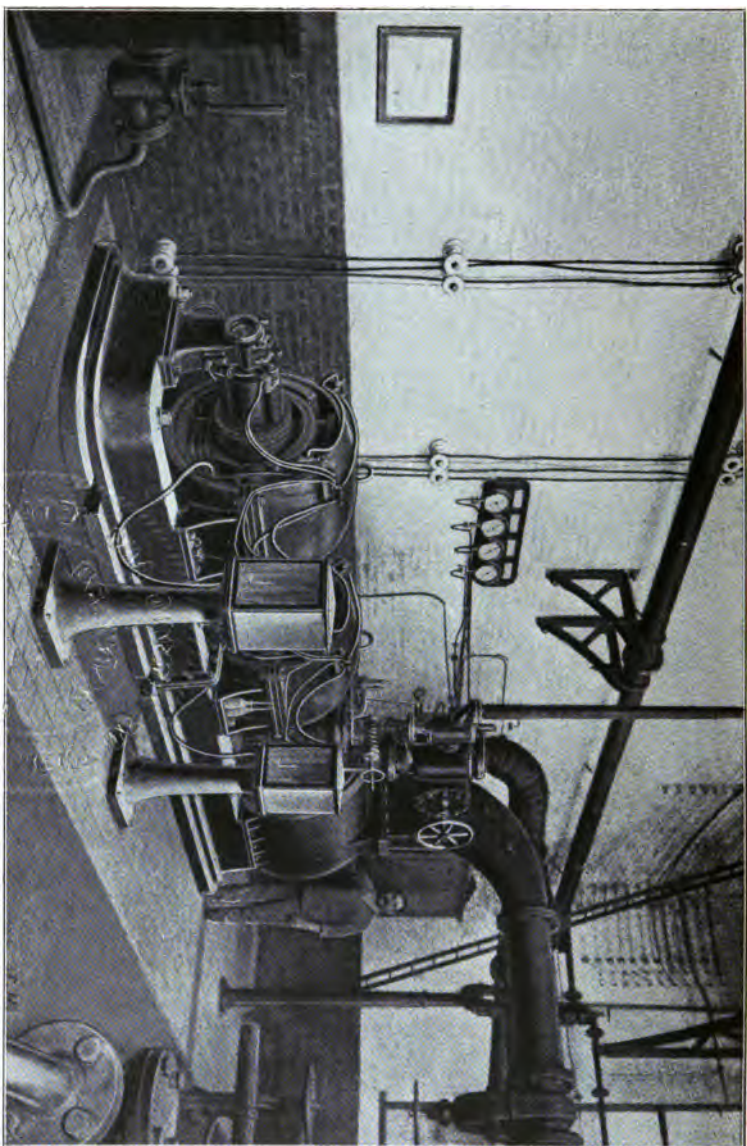


Fig. IV.
220 K. W. EXHAUST STEAM RATEAU TURBINE, DRIVING FIVE DIRECT CURRENT DYNAMOS.



Fig. V.
RATEAU SYSTEM.



Fig. VI.
RATEAU SYSTEM.

Reunion Mines, Spain.—650 H. P., A. C. current.

Mines of Houssu, Belgium.—A. C. current, water-type regenerator, 500 K. W.

Mines of Marnes, France.—A. C. current, water-type regenerator, 250 K. W.

INSTALLATION AT THE STEEL WORKS OF THE STEEL COMPANY
OF SCOTLAND.

The engines to which the Rateau process is applied are :

A tandem reversible engine 36x48 driving a train of rolls. When the mill operates this engine has stoppages varying from a few seconds up to 40 seconds.

An engine, similar to the first, driving a finishing train ; stoppages from 5 seconds to 30 seconds.

Four steam hammers on several auxiliary engines.

The exhaust steam available is estimated at approximately 42,000 pounds per hour. To regularize the exhaust of these engines a steam regenerator has been erected with a capacity of 55 tons of water. This apparatus has been divided into two decks so as to enable the steam to come in contact with a greater surface of water. The entire mass of water is handled in such a way as to participate entirely in the steam regeneration. The dimensions of this apparatus are: 10 feet in diameter by 34 feet in length. In order to diminish the violence of the exhaust of the rolling mills when starting, this regenerator has been fitted with a receiver in which the steam is allowed to expand before reaching the piping of the regenerator. This receiver has also the function of separating the oil contained in the steam.

The installation involves two burbo dynamos of 600 H. P. each. These turbines are of the Rateau type and were built by the Fraser & Chalmers firm, of London. The electrical generators were built by Siemens and give D. C. current at 230 volts. One of these engines has been running for several months.

The regenerator regularizes completely the flux of steam. Powerful exhausts of the rolling mill engines are taken care of,

as well as the intermittance of the output of steam. The diagrams automatically recorded when the mill was in regular running operation show that the variations of pressure in the regenerator were always less than 1.42 pounds per square inch. A recent test has shown that the steam consumption per E. H. P. measured at the switchboard was of 25½ pounds.

Admission pressure being one atmosphere absolute, vacuum 28".

This is quite remarkable and as far as I know shows the highest efficiency ever recorded in steam turbines.

From the estimation of the engineers of the plant the total saving realized by these engines of 900 K. W.'s output, obtained without any cost of fuel, will be as high as \$40,000 per annum.

Lanarkshire Steel, England.—750 H. P.

Hucknall Torkard Co., England.—150 H. P., etc., etc.

Special notice should be taken of the Bethune plant, as the 350 H. P. turbine is used for driving direct-coupled to a Rateau rotary compressor. This is a feature of great interest to mines and steel works managers, as compressed air for compressed air tools, blast furnaces, cupolas, or Bessemer converters can be obtained by utilizing the exhaust steam from hoisting or rolling mill engines.

At the present day, when maximum output with minimum cost is so eagerly sought after, this system offers a ready means of general improvement of working costs of various industries.

The Rateau system, therefore, renders available at a lower cost all the advantages of a large central station without any costs beyond those of installation, and permits of the reduction of steam consumed per H. P. by the combined primary engines and turbines to a minimum not much greater than that attained in highly-perfected electrical installation, at the same time retaining the necessary features of such primary machines, viz., simplicity, steadiness in working, and easy control.

The European Rateau Co. has under running condition, erection or contract 60,000 H. P.

METHODS OF IRON ORE ANALYSIS USED IN THE
LABORATORIES OF THE IRON MINING
COMPANIES OF THE LAKE SUPERIOR
MINING REGION.

BY W. A. SIEBENTHAL, REPUBLIC, MICH.

The idea of compiling the methods used in the laboratories of the iron mining companies of the Lake Superior region, in the analysis of iron ores, was suggested by the work of Francis C. Phillips' "Methods for the Analysis of Ores, Pig Iron and Steel," published by the Engineers' Society of Western Pennsylvania, 1896, and later in book form by the Chemical Publishing company.

The plan therein carried out has been followed in our present work. A letter was addressed to each of the chemists, whose name and address we were able to obtain, requesting a description of the methods used in the analysis of iron ores in the determination of iron, phosphorus, and such other substances as might be determined. The responses were quite general but few of those addressed failing to send in a description of the methods employed. In submitting this collation of methods, we, the chemists of the region, hope that such may be of some interest to mining men and chemists in general and of special interest to the chemists of the Lake Superior district. The intention is not to present a scientific treatise on iron ore analysis but to set forth in detail the methods of procedure carried out in the daily work in the analysis of iron ores, which furnishes the basis for the grading of the ores and the commercial transactions of the mining companies. Because of the limited time allowable for analyses, the accuracy and reliability that results must present, we believe that in the Lake Superior

region the methods employed are as rapid and at the same time as reliable as may be found in use, in any district, in the commercial analysis of iron ores.

That the present compilation is in many respects crude and imperfect we are well aware. We desired and attempted to reach all the chemists of the region and wished to give all an opportunity to contribute to the work. Doubtless some may have been missed which we regret, and there may be others who have worked up some methods that at present they do not care to give out. However because of the general responses to our letter and of the geographical distribution of the same we feel that the present attempt at compilation fairly well represents the present status of analytical chemistry of iron ores of the district. The reports coming from the chemists of the different mining sections are distributed as follows: From Minnesota five, representing the Vermilion and Mesabi ranges, from the Gogebic range six, from the Menominee range six, from the Crystal Falls district two, from the Marquette range four, from the Baraboo district, Wisconsin, two and from Ontario one. Total twenty-six. An examination of the reports shows the following general data.

Two methods are in general use in the determination of iron: One, the permanganate method, is used by seventeen chemists, the other, the bichromate method by nine.

In the determination of phosphorus three general methods are described with varying modifications in manipulation. One the handy Alkalimetric method in which the phosphorus is precipitated as yellow ammonium phospho-molybdate, dissolved in standard sodium hydrate, and titrated with standard nitric acid, is used by thirteen of the chemists; the Emmerton method in which the yellow precipitate is dissolved in ammonium hydrate, reduced with zinc and sulphuric acid, and titrated with potassium permanganate, is used by seven; and a modification of the Wood method, described in Blair's "Chemical Analysis of Iron," in which the phosphorus is determined gravimetrically by weighing the yellow ammonium phospho-molybdate precip-

itate, is used by five of the chemists. In a few cases two of the three methods are reported.

Three methods of more than the usual rapidity are described, one by F. A. Janson, of Vulcan, another by John McNamara, of Ironwood, and a third by W. A. Siebenthal, of Republic, Mich., all being modifications of the handy method.

In the determination of silica two methods are described. The sodium carbonate fusion method is used by eleven; the hydrofluoric acid method by six; both being used by some of the chemists.

Volhard's method for manganese, with varying modifications, is used by fourteen of the chemists; Julien's method by two; and a gravimetric process is described by one.

Of those reporting methods for the determination of calcium, nine use a gravimetric method, precipitating the calcium as calcium oxalate; igniting and weighing as calcium oxide. One uses a gravimetric process, titrating with potassium permanganate.

Magnesia is determined gravimetrically as magnesium pyrophosphate by nine and alumina as aluminum phosphate by a like number of the chemists who report methods for such determinations.

Sulphur is determined as barium sulphate by those reporting on the determination.

One chemist describes a method for the determination of titanium.

Methods for moisture determination are described by four chemists, and a like number report methods for organic and volatile matter.

The interest and value of this collation of methods, to the chemists of the region, it seems to me, lies in and is to be obtained from the differences in detail and manipulation as well as in the general differences of methods. Already have I found myself making some changes in my own work, applying some of the details given by some of the chemists in their descrip-

tions. In conclusion while the methods described may be as rapid and reliable as any in general use, it seems to me that there is a possibility for improvement and an excellent opportunity for research along the line of both shortening and simplifying some of the methods given, especially in the determination of phosphorus.

A method for the direct oxidation and dissolving of the phosphorus without the complete solution of the ore would considerably shorten the process. The two methods given for the determination of iron are quite simple when compared to those described for other substances, yet each has certain objections; the permanganate method because of the inconstancy of strength of the solution; the bichromate method is slower and requires the use of an external indicator. An internal indicator would be a decided improvement in the latter method.

We are indebted to Mr. D. T. Morgan and Mr. Wm. Kelly for courtesies and aid extended in the compilation of the work and also desire to thank the other superintendents and general managers who have co-operated in the work in furnishing us with the names and addresses of their chemists or who referred our letter of inquiry to the chemists in charge of the laboratory work.

I. METHODS USED AT THE LABORATORY OF THE OLIVER IRON MINING COMPANY, VERMILION RANGE, ELY, MINN.

BY CLARENCE J. MOTT.

DETERMINATION OF IRON.

Weigh .5 gram of ore into a No. 0 Griffin beaker. Add 5 cc. stannous chloride, 10 cc. hydrochloric acid and heat until in solution. Remove from hot plate and complete the reduction with stannous chloride solution, adding 1 or 2 drops in excess, and allow to cool. Pour into a No. 4 beaker and dilute to 300 cc. with water. Add 2 or 3 cc. of saturated solution of mercuric chloride, to precipitate any excess of tin, and 20 cc. of

titrating solution. Stir; place under a burette and titrate with a standardized solution of potassium permanganate.

SOLUTIONS.

Potassium Permanganate Solution.—4.417 grams potassium permanganate to 1 liter of water.

Stannous Chloride.—100 grams of stannous chloride dissolved in 500 cc. hydrochloric acid and made up to 1 liter with water.

TITRATING SOLUTION.

- A. 16 grams of manganese sulphate, and 16 cc. of water.
- B. 33 cc. of phosphoric acid and 47 cc. water.
- C. 32 cc. sulphuric acid and 48 cc. water.

Make up separately and when in solution and cool, mix all together and shake.

DETERMINATION OF TOTAL PHOSPHORUS.

Weigh three grams of ore into a No. 2 beaker; add 25 cc. hydrochloric acid and dissolve on the hot plate. When in solution oxidize with a few drops of nitric acid, and evaporate to 10 cc. Remove from plate and filter into a 16 oz. flask. Fuse the insoluble residue with sodium carbonate. Dissolve the fusion with water; acidulate with hydrochloric acid; evaporate to dryness, and dehydrate. Redissolve in water, using a few drops of hydrochloric acid, and filter into the original filtrate. Precipitate the iron with ammonium hydrate, adding a few drops in excess; neutralize with nitric acid; heat to 60°C. and precipitate the phosphorus with 25 cc. of molybdate solution. Shake well and allow to settle for one hour. Filter and wash free of iron with solution of ammonium sulphate, washing three times by decantation and five times on filter. Place the funnels containing the yellow precipitate over the flasks, in which the phosphorus was precipitated, and dissolve the precipitate in 20 cc. ammonium hydrate (1:3) solution. Reduce with 10 grams of granulated zinc and 75 cc. sulphuric acid (1:4) solution. Bring to boil on the hot plate; filter, wash with water and titrate with the same potassium permanganate solution as used for the determination of iron.

SOLUTIONS.

Molybdate Solution.—Dissolve 100 grams of molybdic acid in 400 cc. ammonium hydrate (sp. gr. .96) and add to

1500 cc. nitric acid (sp. gr. 1.20), shaking well after each addition.

Ammonium Sulphate Solution.—27½ cc. ammonium hydrate and 24 cc. sulphuric acid. Make up to a liter with water.

DETERMINATION OF INSOLUBLE PHOSPHORUS.

Weigh 5 grams of ore into a No. 3 beaker; add 30 cc. hydrochloric acid; dissolve on hot plate. When in solution, oxidize with nitric acid; evaporate to dryness and dehydrate. Redissolve and filter. Fuse the insoluble residue with sodium carbonate. Dissolve the fusion in water and acidulate. Evaporate to dryness and dehydrate. Cool; redissolve in water, using a few drops of hydrochloric acid, and filter to aid in neutralizing and proceed as for total phosphorus.

DETERMINATION OF SILICA.

Weigh 1 gram of ore into a No. 1 beaker; add hydrochloric acid and dissolve on hot plate. Evaporate to dryness and dehydrate. Cool; redissolve with a few drops of hydrochloric acid and filter, carefully rubbing the beaker. Fuse the insoluble residue with sodium carbonate. Dissolve the fusion with water; acidulate; evaporate to dryness and dehydrate. Redissolve the fusion in water, using a few drops of hydrochloric acid. Filter, and wash 12 times with hot water, rubbing the inside of the beaker well with a policeman. Ignite and weigh as SiO_2 .

DETERMINATION OF MANGANESE.

Volhard's method as given on page 118, third edition of Blair's "Chemical Analysis of Iron," modified to suit these ores, is used.

DETERMINATION OF ALUMINA.

Peter's modification of Wohler's method as given on page 251, third edition of Blair's Chemical Analysis of Iron is followed in detail.

DETERMINATION OF CALCIUM AND MAGNESIA.

The method described in "Methods for the Analysis of Limestone", page 267, third edition of Blair, is used.

DETERMINATION OF SULPHUR.

The method used is that given on page 51, N. W. Lord's Notes on Metallurgical Analysis.

II. METHODS USED AT THE MOUNTAIN IRON LABORATORY OF THE OLIVER IRON MINING CO., MOUNTAIN IRON, MINN.

By A. T. GORDON.

DETERMINATION OF IRON.

By the Zimmerman-Reinhardt method. See Blair, page 216.

The method is the same as described by C. J. Mott, with the following exception: "Drive off the excess of free acid after all the iron is in solution".

CAUTIONS.

Always titrate in a cold solution. Dilute as near as possible to the same amount each time, with the conditions the same as when treating a standard ore. Titrate as quickly as possible, but not so rapidly but that the pink color of the permanganate will instantly disappear as the solution is being stirred. It is only when, on adding the mercuric chloride, a silky appearance is noted, that the results can be relied upon. Introduce mercuric chloride but once to the cooled iron solution. Time required from 15 to 25 minutes. In a case of rush the determination can be made in 10 minutes or less.

SOLUTIONS.

Potassium Permanganate Solution.—36 grams of potassium permanganate to 8,000 cc. water; heat to 212°F. Cool and decant into a black painted carboy. Make up one carboy or about 48 liters at a time.

Titration Solution.—320 grams manganese sulphate dissolved in 1,000 cc. water. 660 cc. phosphoric acid mixed with 1,000 cc. water. 640 cc. sulphuric acid added to 1,500 cc. water. Mix.

Stannous Chloride Solution.—200 grams of stannous chloride to 200 cc. hydrochloric acid; heat; dilute with 2,300 cc. water.

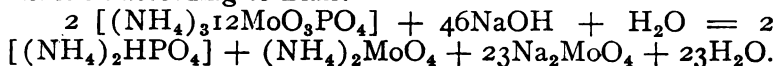
Mercuric Chloride Solution.—A saturated solution.

DETERMINATION OF PHOSPHORUS.

By the Handy method. See Blair, page 104.

Treat 3 grams of ore in a No. 2 beaker with 40 cc. hydrochloric acid, (sp. gr. 1.20) and evaporate off the free acid or until about 15 cc. remains, after all the ore is dissolved. Add about 2 cc. nitric acid and heat for a few minutes until certain

that all phosphorus is oxidized, and the solution does not exceed 10 to 15 cc. Be careful to avoid the formation of ferric oxide on the sides of the beaker, or if it does form, wash it down with a few drops of hydrochloric acid. Dilute with a little water and filter through a No. 597, 11 cm. filter into a 400 cc. Erlenmeyer flask. Use the least possible amount of water for washing, not exceeding 60 to 75 cc. Wash once with 1:1 hydrochloric acid before the last two washings with water. Neutralize, adding about 12 cc. ammonium hydrate (sp. gr. .90) and then enough nitric acid (sp. gr. 1.42) to make the color of the solution a shade darker than amber. Heat to 65 or 70°C. and precipitate the phosphorus with the addition of 40 cc. molybdate solution and shake a few minutes. When the precipitate has settled filter through a No. 0 J.H.M. 9 cm. filter and wash five times with 1% nitric acid and five times with 1% potassium nitrate solution or until certain that all acid has been washed out of the paper and precipitate. Fold the paper containing the precipitate and introduce it into the flask previously used, after thoroughly rinsing the same. Unfold the paper and add 15 cc. standard sodium hydrate. Shake carefully to dissolve the precipitate. Add 3 drops of phenolphthalein solution, and titrate the excess of alkali with standard nitric acid. Reaction according to Blair.



CAUTIONS.

Be sure that the proper neutral point has been obtained before precipitating with the molybdate solution. If too near the alkaline point iron will come down with the phosphorus; if too acid the phosphorus will be slow in coming down, or will not precipitate. Too much care cannot be exercised in freeing the filter-paper from acid. Do not allow the yellow precipitate to stand long exposed after it has been washed, as the standard alkali, being so weak, is easily affected. Owing to the tendency of the water standing in the carboys to absorb acid fumes and carbon dioxide from the air, the least possible amount should be used in the titration.

SOLUTIONS.

Standard Sodium Hydrate.—Dissolve 335 to 350 grams caustic soda (depending on the purity) in about 8000 cc. water and add sufficient barium hydrate to precipitate the carbonate,

and filter. Dilute to 45,000 cc. 1 cc. is equivalent to .007 per cent. of phosphorus when a 3 gram sample is taken.

Standard Nitric Acid.—Add 400 cc. nitric acid (sp. gr. 1.42) to about 45,000 cc. water. Titrate and make equivalent to the standard alkali.

Nitric Acid Wash Solution.—500 cc. nitric acid to one carboy of water.

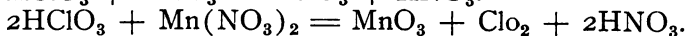
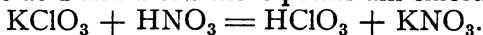
Potassium Nitrate Wash Solution.—454 grams potassium nitrate dissolved in 700 cc. water and diluted to one carboy.

Molybdate Solution.—5 lbs. Merck's c.p. molybdic acid, dissolved in a solution of 5820 cc. water and 3230 cc. ammonium hydrate. When in solution pour slowly and with constant stirring into a cold mixture of 12,800 cc. nitric acid and 21,100 cc. water. Add to the mixture .2 grams of sodium hydrogen phosphate. When the solution is perfectly clear, siphon off for use, filtering if necessary.

DETERMINATION OF MANGANESE.

Julien's method. (See Classen, page 282).

Treat 2 grams of ore in a No. 3 beaker with from 30 to 45 cc. hydrochloric acid. Evaporate to about 15 cc. or to dryness if the ore is low in manganese. Add 45 cc. nitric acid and boil off the nitric oxide fumes and the hydrochloric acid. Introduce into the boiling nitric acid solution at two or three different times, about $2\frac{1}{2}$ grams of potassium chlorate. If the manganese dioxide is slow in coming down add a little more nitric acid and a few more potassium chlorate crystals,



When the solution with the precipitate has been reduced to about 20 cc. remove from the hot plate and cool. Add about 200 cc. water and introduce from the burette, 10 to 15 cc. hydrogen dioxide, depending on the amount of manganese dioxide to be dissolved, and also on the strength of the hydrogen dioxide solution used. Titrate back with standard potassium permanganate. The number of cc. potassium permanganate required deducted from the hydrogen dioxide blank, times the factor for 2 grams gives the percent of manganese.

CAUTIONS.

If the ore contains a large amount of silica much care will be necessary to avoid bumping. If the ore is low in manganese, which is the rule with most of the ores here, it is best to make a second addition of nitric acid and potassium chlorate. Be sure

that all chlorine is expelled after the last addition of potassium chlorate. Always use cold water in diluting the nitric acid containing the manganese dioxide precipitate. As the precipitate has a tendency to adhere to the bottom and sides of the beaker, it will sometimes be necessary to loosen such with a stirring rod. Titrate as soon as possible after the precipitate has been dissolved by the hydrogen dioxide.

DETERMINATION OF SILICA.

Hydrofluoric acid method. (See Treadwell's Qualitative Analyses, page 357).

Treat .5 gram of ore 10 to 15 cc. hydrochloric acid. Drive off the excess of acid and filter on a No. 589, 9 cm., white ribbon paper. Wash several times with water and once with hydrochloric acid, then with water until the paper is free of iron. (*Filtrate A.*) Ignite the moist paper with the residue in a platinum crucible, slowly at first, then at the required blast to burn off all carbon. Cool and weigh. Moisten the weighed residue with 2 cc. water and 3 drops of sulphuric acid; and add just enough hydrofluoric acid to cause everything in the crucible to go into solution. Heat the crucible on an asbestos board. Drive off the hydrofluoric and sulphuric acid slowly, then heat in the flame of the blast lamp until everything in the crucible is oxidized. Cool and weigh. The difference of the two weights will give the weight of SiO_2 . When soluble silica exists in the ore dehydration by baking on the hot plate will be necessary.

DETERMINATION OF ALUMINA.

Phosphate method.

Save Filtrate A. from the insoluble residue when making the silica determination. Fuse the residue obtained after the final weighing for silica, with $\frac{1}{2}$ gram of sodium carbonate. Dissolve the fusion in dilute hydrochloric acid and combine with filtrate A. Bring the volume of this filtrate to about 200 cc. and add 20 cc. ammonium phosphate. Add a few drops of methyl orange solution, and bring the solution containing everything in the ore but the silica, to the neutral point by slowly adding ammonium hydrate, keeping the solution well stirred. Add just enough strong hydrochloric acid to redissolve the precipitate formed by the addition of ammonium hydrate. To the clear solution add 25 to 30 cc. of sodium thio-sulphate to reduce the ferric to ferrous iron. Dilute to 300 cc. Heat on hot plate. When the solution begins to boil, introduce

10 or 12 cc. (1:1) acetic acid and continue the boiling 30 minutes, or until the acid is mostly expelled. Filter on a No. 589 B.R. paper and wash ten times as quickly as possible with hot water. Introduce the filter with precipitate into a porcelain crucible and carefully ignite until all carbon is burned, then with the full blast of the lamp. Cool and weigh as AlPO_4 . Use the tables for obtaining the percentage of Al_2O_3 in the sample.

SOLUTIONS.

Ammonium Phosphate Solution.—200 grams of ammonium phosphate dissolved in 1,000 cc. water and diluted to 2,500 cc.

Sodium Thiosulphate Solution.—1,000 grams of sodium thiosulphate dissolved in 1,000 cc. water and diluted to 2,500 cc.

Methyl Orange Solution.— $\frac{1}{2}$ gram methyl orange dissolved in 300 cc. hot water. When cold filter if necessary.

REMARKS.

The above notes are such as we hand out to the men and serve as a guide to them, rather than a full description of the methods, most of which are fully described in the works referred to, the deviations being noted.

The modified method for aluminum, as we use it, may be of some interest as I do not think that it is elsewhere described, the present modifications having mostly originated with us.

In regard to the elements, lime, magnesia, sulphur, soda and potassa, they are determined only in completes and one or other of the standard methods are used with slight modifications to suit our conditions.

For magnesium, see "Treadwell's Quantitative Analysis", page 71.

For sulphur, the same, page 277, and Hillebrand, bulletin of the United States Geological Survey 1900, page 106.

Combined water and organic matter are determined as loss on ignition by heating one gram of ore in a platinum crucible for from ten to fifteen minutes at a low red heat.

We have compiled tables to correspond to the weights and solutions described in the notes for iron, phosphorus, manganese and aluminum.

III. METHODS USED IN THE LABORATORY OF THE OLIVER IRON MINING COMPANY, HIBBING, MINNESOTA.

By E. T. GRIESE.

The methods used in the determination of iron and phosphorus are essentially as given in Lord's "Notes on Metallurgical Analysis".

Manganese is determined by Volhard's method with the following slight modification: Neutralize the excess of acid and precipitate the iron with zinc oxide alone, titrating direct without filtering.

Silica is determined by the regular hydrofluoric method.

IV. METHODS USED AT THE LABORATORY OF THE OLIVER IRON MINING COMPANY, EVELETH, MINNESOTA.

By H. S. SHERMAN.

The Zimmerman-Reinhardt method, titrating with potassium permanganate solution, is used in the determination of iron.

For the determination of phosphorus both the Emmerton method, by reduction with zinc, and the Handy standard alkali method, described in Phillips', "Methods of Iron Analysis", are used. The Wood gravimetric method described in Blair's, "Chemical Analysis of Iron", is used to check the above methods.

For the determination of other substances, methods given in Blair or in Lord's "Notes on Metallurgy", are followed.

V. METHODS USED AT THE LABORATORY OF CORRIGAN, MCKINNEY & CO., STEVENSON MINE, HIBBING, MINN.

By R. S. BROWN.

DETERMINATION OF IRON.

Weigh .5 gram sample into a No. 0 beaker. Add 2 cc. stannous chloride solution and 15 cc. hydrochloric acid. Cover and put on hot plate until in solution. "Do not boil". Reduce with stannous chloride, adding a slight excess. Add 15 cc. mercuric chloride which should give a silky precipitate of mercurous chloride that aids materially in detecting the end reac-

tion. Titrate with potassium permanganate solution, in 200 cc. cold water and 40 cc. titrating solution.

SOLUTIONS.

Potassium Permanganate Solution.—135 grams potassium permanganate dissolved in hot water and made up to 45 liters in distilled water.

Titration Solution.—480 grams manganese sulphate, 5,250 cc. distilled water, .990 cc. phosphorus acid, 960 cc. sulphuric acid.

Stannous Chloride —1 lb. stannous chloride, 100 cc. distilled water, 400 cc. hydrochloric acid. When in solution dilute to 2,000 cc. with distilled water.

Mercuric Chloride.—100 grams mercuric chloride, 2,000 cc. hot distilled water.

DETERMINATION OF PHOSPHORUS.

Weigh a 3 gram sample into a No. 2 beaker. If the ore is refractory add 2 to 4 cc. stannous chloride. Add 30 cc. hydrochloric acid, cover and boil until the ore is in solution. Add 1 cc. nitric acid to thoroughly oxidize the phosphorus and bring the iron into a ferric condition. Boil until nitric fumes disappear. Filter into a 16 oz. flask, using as little wash water as possible. Neutralize with ammonia and redissolve the precipitated iron with nitric acid, avoiding an excess of acid. Heat filtrate to 80°C. and add 40 cc. molybdate solution. Whirl solution until thoroughly mixed and let stand until settled. Filter through a 11 cm. fast filter. Wash the flask thoroughly with 1% nitric acid solution. Wash the paper and ammonium phosphomolybdate precipitate thoroughly 5 or 6 times with 1% solution of potassium nitrate. Rinse the flask, in which precipitation was made, and add 50 cc. sodium hydrate solution. Introduce the filter paper with precipitate into the flask, cork and shake vigorously until the precipitate is in solution and the paper broken up. Remove the stopper, rinsing carefully, with water, into the flask any adhering liquid or paper. Add 5 drops phenolphthalein indicator, and titrate with standard nitric acid until a very faint pink color remains. The difference between the number of cc. of standard sodium hydrate and nitric acid used multiplied by the phosphorus factor of 1 cc. of standard sodium hydrate gives the percent. of phosphorus. The factor is found by "running" a standard phosphorus sample in which the phosphorus has been accurately determined.

SOLUTIONS.

Standard Sodium Hydrate.—145 grams sodium hydrate to 45 liters distilled water.

Standard Nitric Acid.—216 cc. nitric acid (sp. gr. 1.42) to 45 liters distilled water.

MOLYBDATE SOLUTION.

A. 2,000 cc. distilled water, 500 cc. ammonia, 500 grams molybdate acid. Cool.

B. 3,000 cc. distilled water, 2,000 cc. nitric acid. Cool.

Add A. to B., with constant shaking.

Potassium Nitrate Solution.—1 gram potassium nitrate to 100 cc. distilled water.

Nitrate Acid Solution.—1 cc. nitrate acid to 100 cc. distilled water.

Phenolphthalein Solution.— $\frac{1}{2}$ gram, dissolved in 200 cc. 95% alcohol and diluted to 400 cc. with water.

DETERMINATION OF SILICA.

Two methods, fusing with sodium carbonate and volatilizing with hydrofluoric acid, are used. See Blair's "Chemical Analysis of Iron", fourth edition, p. 236.

DETERMINATION OF MANGANESE.

Weigh 1 gram of ore into an 8 oz. beaker. Add 20 cc. hydrochloric acid and place on hot plate until the ore is dissolved. Add 1 cc. nitric acid and evaporate to a syrup. Add 200 cc. hot water and enough zinc oxide to obtain a fawn colored precipitate. Boil and titrate while hot with potassium permanganate solution as used for iron determination. The heavy precipitate of zinc and iron carries down the manganese precipitate rapidly so that reheating is not necessary.

DETERMINATION OF LIME AND MAGNESIA.

Weigh 1 gram of ore into an 8 oz. beaker. Add hydrochloric acid and evaporate to dryness twice. Redissolve in hydrochloric acid and filter. Burn and fuse the insoluble residue with sodium carbonate. Transfer the fused mass to an evaporating dish and reduce to dryness twice, keeping it acid with hydrochloric acid. Cool, dissolve in warm dilute hydrochloric acid and filter into the first filtrate. Add a few drops of acetic acid to the combined filtrates and precipitate the iron, aluminum and manganese with an excess of ammonia. Boil for a few minutes and filter. To the filtrate, add 10 cc. ammonium

hydrate and 5 cc. ammonium oxalate; boil and allow to settle. Filter on an ashless filter; wash with hot water; burn and weigh as CaO .

Magnesia.—To the lime filtrate add about one-third the volume, of the solution, of ammonia and 5 or 6 cc. strong solution of sodium ammonium phosphate. Stir vigorously and set in a cool place for 8 to 12 hours. Filter and wash with a 1:3 solution of ammonia and water, containing 10 grams of ammonium nitrate per 100 cc. Burn and weigh as magnesium pyro-phosphate. ($\text{Mg}_2\text{P}_2\text{O}_7$).

DETERMINATION OF ALUMINUM.

Weigh 1 gram of ore into an 8 oz. beaker. Add 20 cc. hydrochloric acid and evaporate to dryness; repeat. Redissolve in hydrochloric acid and filter into a 16 oz. flask. Burn and fuse the insoluble residue with sodium carbonate. Transfer the fused mass to an evaporating dish. Add hydrochloric acid and evaporate to dryness, twice. Take up in hot, dilute hydrochloric acid and filter into the first filtrate. Add ammonia to the combined filtrates until the solution is very dark red, but perfectly clear. Add about 3.5 cc. hydrochloric acid and let stand a few minutes, when the solution should assume the usual ferric iron color which may require a few drops of hydrochloric acid. The solution, at this point, must be cool. Add 3 or 4 cc. of saturated solution of sodium ammonium phosphate and agitate until the solution is clear. Add 15 cc. acetic acid and while shaking add sodium-hypo-sulphite solution until the iron is reduced. Place the flask on the hot plate and let boil for 15 to 25 minutes, and filter while hot. Wash with hot water; burn, and weigh as AlPO_4 .

DETERMINATION OF SULPHUR.

Weigh 2 grams of ore into an 8 oz. beaker. Add 30 cc. hydrochloric acid and when ore is in solution 2 to 3 cc. nitric acid and evaporate to dryness. If much iron pyrites shows in beaker add 5 to 10 cc. nitric acid and boil until dissolved. Add hydrochloric acid and evaporate to "hard" dryness a second time. Take up with a small amount of hydrochloric acid and filter into a 12 oz. flask. Carefully add ammonia to neutralize any great excess of hydrochloric acid. The solution should not be more than 50 cc. at this point. If so boil down and while hot add 3 or 4 cc. saturated solution of barium chloride and set in a warm place to settle. Siphon off the clear liquid, filter and

wash the precipitate with hot, dilute hydrochloric acid and hot water. Burn and weigh as BaSO_4 .

VI. METHODS USED AT THE LABORATORY OF THE NEWPORT MINING COMPANY, IRONWOOD, MICH.

By JOHN McNAMARA.

DETERMINATION OF IRON.

Weigh about .6 gram of the ore into a 2 oz. usual form beaker. Add 7 cc. stannous chloride and dissolve on hot plate or sand bath. To the hot solution, stannous chloride is added until the solution is colorless. Heat for about a minute longer and if the reduction is complete, remove from hot plate. When cool add from a burette 15 cc. titrating solution. Wash into an 8 oz. glass; fill about two-thirds full of water and titrate with potassium permanganate. 1 cc. equals one percent of iron.

SOLUTIONS.

Stannous Chloride.—Dissolve 70 grams of mossy tin in an acid bottle containing about $2\frac{1}{2}$ liters of hydrochloric acid.

For the reduction of iron in the determination a solution of about four times this strength is used.

Titrating Solution.—Dissolve 240 grams of manganese sulphate in 3,000 cc. of water. Add 500 cc. syrupy phosphoric acid and 500 cc. sulphuric acid. Pour this while hot into two bottles containing about one pound of mercuric chloride and shake a few times.

Potassium Permanganate.—150 grams to 45 liters of water. To standardize this solution, weigh .6 gram of standard ore, dissolve and treat as indicated above. The percentage of iron in the standard ore times .6 (the weight of ore taken) divided by the burette reading equals the amount of ore to be weighed so that 1 cc. will represent one percent of iron.

DETERMINATION OF PHOSPHORUS.

Weigh $2\frac{1}{2}$ grams of ore into an 8 oz. Griffin beaker. Add about 40 cc. hydrochloric acid; dissolve on hot plate and evaporate to a syrup. Filter into an 8 oz. Erlenmeyer flask and wash filter with 30 cc. of water. Heat to 85°C . and add 30 cc. molybdic acid solution. Shake well and let settle for 15 minutes. Filter; carefully wash the precipitate adhering to the

flask on to the filter. Wash the precipitate and filter, six times with water or until all acid is removed. Rinse the flasks thoroughly at tap to remove all traces of acid. Place the filter containing the precipitate into the flask; add 25 cc. of potassium hydrate solution and dilute with water to 50 cc. Stopper, with a rubber stopper, and shake to break up the filter and dissolve the precipitate. Add 3 drops of phenolphthalein solution and titrate the excess of alkali with standard nitric acid. The difference between the number of cc. of alkali and acid used, times, .002 equals the percent of phosphorus.

A MORE RAPID METHOD FOR THE DETERMINATION OF PHOSPHORUS.

The following rapid method is used when results are wanted quickly: Dissolve $2\frac{1}{2}$ grams of ore in 15 cc. of stannous chloride; evaporate to a syrup and filter. Wash with 30 cc. water; heat to 85°C . and add 30 cc. molybdic acid solution. Heat on hot plate until the solution changes to a dark color and then back to the original color. Put a rubber stopper in the flask, wrap in a towel to retain heat, and shake for three minutes. Filter; proceed as in the regular method. A determination can be made in thirty minutes by this method.

FOR INSOLUBLE PHOSPHORUS.

Burn the residue, from first filtration, in a platinum crucible over a blast lamp for five minutes. Place in a beaker and add 10 cc. nitric acid and 20 cc. water. Bring to boiling point, filter and wash. Add 5 cc. ammonia; heat to 75°C . and add 15 cc. molybdic acid solution. Proceed as with the determination of soluble phosphorus.

SOLUTIONS.

Molybdic Acid Solution.—500 grams of molybdic acid are dissolved in 500 cc. water and 1,500 cc. ammonium hydrate. Add this to a solution containing 2,950 cc. nitric acid and 3,300 cc. water.

Potassium Hydrate Solution.—About 3 grams of potassium hydrate to a liter of water.

Standard Nitric Acid.— $2\frac{1}{2}$ cc. nitric acid to a liter of water.

DETERMINATION OF MANGANESE.

Weigh about .9 gram of ore into an 8 oz. usual form

beaker. Add 15 cc. hydrochloric acid; dissolve on hot plate and evaporate to a syrup. Add 50 cc. of water and nearly neutralize with sodium carbonate solution. Introduce 7 grams of dry zinc oxide and shake until all iron separates as hydroxide. Fill the beaker about four-fifths full of water; heat to boiling and titrate quickly with potassium permanganate, stirring well with a glass rod after each addition.

To find the factor weigh so that 1 cc. of the permanganate solution is equivalent to .2 percent of manganese, multiply the weight of the sample for the iron determination by 2.95 and divide by 2.

Where more than 5 percent of manganese is present, a larger beaker and more water is necessary.

SOLUTIONS.

Sodium Carbonate Solution.—500 grams of sodium carbonate, dissolved in $2\frac{1}{2}$ liters of water.

Potassium Permanganate.—The same as used in the iron determinations.

VII. METHODS USED AT THE LABORATORY OF THE MONTREAL MINING COMPANY, HURLEY, WIS.

BY FRED ANDERSON.

DETERMINATION OF IRON.

Weigh out .5 gram of ore; dissolve, by boiling, in a 6 oz. usual form beaker with 30 cc. hydrochloric acid (sp. gr. 1.20) and 10 to 15 drops of stannous chloride. When dissolved add carefully, drop by drop, stannous chloride until the yellow ferrous solution becomes colorless. Cool; add 20 to 30 cc. mercuric chloride all at once; stir and titrate immediately with potassium bichromate solution using potassium ferricyanide for an indicator.

SOLUTIONS.

Potassium Bichromate Solution.—4.6 grams of the salt to one liter of water. 32 liters of the solution are made at a time.

Stannous Chloride Solution.—100 grams stannous chloride, 135 cc. hydrochloric acid and 800 cc. water.

Mercuric Chloride.—A saturated solution.

DETERMINATION OF PHOSPHORUS.

Weigh out $3\frac{1}{2}$ grams of ore. Put into an 8 oz. Griffin

beaker; add 30 cc. of strong hydrochloric acid; cover and dissolve by boiling. When dissolved remove the cover; evaporate to dryness and take up with from 5 to 10 cc. nitric acid. Heat gently until all nitric fumes are driven off; dilute with small volume of water and filter into an 8 oz. Erlenmeyer flask, using a 9 cm. R.F.P. filter-paper. Wash the filter well with 2% nitric acid solution. Add 25 cc. ammonia and about 15 cc. nitric acid, bringing the solution to a straw yellow color. Heat to 80°C. Add about 40 cc. ammonium molybdate solution and shake for five minutes. Let settle. Filter and wash at least four times with 1% nitric acid solution, and eight times with water. Filter through a 9 cm. Swedish filter paper. After rinsing the flask place the filter paper containing the precipitate into it and add 10 cc. standard sodium hydrate solution. Shake until the paper is broken up and the precipitate dissolved; wash down the sides of the flask and add a few drops of phenolphthalein indicator. Titrate with a standard nitric acid solution to the disappearance of the red color. The difference between the number of cc. of alkali and acid used times the phosphorus factor of one cc. of the alkali gives the percentage of phosphorus.

SOLUTIONS.

Molybdate Solution.—Dissolve 450 grams of Merck's molybdic acid in 1,200 cc. water and 700 cc. of ammonia, in a stone jar. Add 350 cc. nitric acid to partially neutralize the ammonia in the solution. Into each of four 2½ liter bottles pour a mixture of 500 cc. nitric acid and 1,200 cc. water. Pour 550 cc. of the molybdate solution through a funnel into each bottle and mix thoroughly by a slight rotary motion and the solution is ready for use. Be careful to keep the end of the funnel above the solution, or a white precipitate will come down.

Nitric Acid Solution.—146 cc. nitric acid (sp. gr. 1.42) to 10 liters of water.

Sodium Hydrate Solution.—154 grams c.p. sodium hydrate to 10 liters of water. Dissolve in water; filter through asbestos and it is ready for use.

DETERMINATION OF MANGANESE.

Weigh 1 gram of ore into a small beaker; add 20 cc. of strong hydrochloric acid; cover with watch-glass and boil until dissolved. Remove cover and evaporate to a small volume and dilute with 10 cc. water. Pour into a 16 oz. flask and add sodium carbonate solution until a dark red color appears; then

zinc oxide solution until a precipitate appears. Add 50 cc. water and boil. Titrate while hot, with potassium permanganate to a faint red color.

Potassium Permanganate Solution.—3.69 grams of potassium permanganate to a liter of water. Twice the number of cc. used gives the percent of manganese, when 1 gram of ore is taken.

VIII. METHODS USED AT THE LABORATORY OF THE OLIVER IRON MINING COMPANY, IRONWOOD, MICH.

BY EDWARD A. SEPARK.

DETERMINATION OF IRON.

Dissolve the factor weight of the sample in a 6 oz. usual form beaker with 30 cc. hydrochloric acid (sp. gr. 1.20) and 5 to 10 drops of stannous chloride, by boiling. Cover with a watch-glass. After all is dissolved, as is shown by the white residue, add carefully, drop by drop, to the hot solution, a solution of stannous chloride, with constant stirring until the yellow, ferric solution becomes a colorless, ferrous solution. Cool to the temperature of running water; add 10 to 20 cc. saturated mercuric solution all at once, and titrate immediately with potassium dichromate solution to the end of any color in the indicator drop. The burette reading gives the percentage of iron.

SOLUTIONS.

Potassium Dichromate Solution.—4.4 grams of the salt to one liter of water. Thirty liters of the solution are made up at a time.

Stannous Chloride Solution.—100 grams of stannous chloride dissolved in 130 cc. hydrochloric acid and diluted with 750 cc. water.

Potassium Ferricyanide Solution (Indicator).—About 1 gram of the crystals dissolved in 100 cc. water. Ten cc. of this solution is diluted to 100 cc. and used for the final reaction, as it is more delicate.

DETERMINATION OF PHOSPHORUS.

Dissolve the factor weight of sample in an 8 oz. Griffin beaker with watch-glass cover, with 50 cc. hydrochloric acid; evaporate to dryness and take up with 5 to 10 cc. nitric acid.

Heat gently until all nitrous fumes are driven off. This is done to oxidize everything and break up any organic substance present. Dilute with a small quantity of water and filter into an 8 oz. Erlenmeyer flask. Wash the insoluble matter well. Precipitate the iron, alumina, manganese and phosphorus with ammonium hydrate and redissolve in nitric acid, bringing the solution to a straw-yellow color (which indicates the proper degree of acidity), for the entire precipitation of ammonium phosphomolybdate. Heat the solution to 85°C. (a higher temperature is likely to break up the molybdate solution, precipitating molybdic acid). Add about 30 cc. molybdic solution (which is enough to precipitate .700 percent of phosphorus), and agitate the flask, by shaking, for five minutes. Let the precipitate settle before filtering. Filter and wash at least three times with 1 percent nitric acid and four times with water or until free of acid. Introduce the filter with precipitate into a clean 8 oz. Erlenmeyer flask and dissolve in 10 cc. of sodium hydrate solution. Shake vigorously until the paper is broken up and all the yellow precipitate is dissolved. Wash down the sides of the flask and add a few drops of an alcoholic solution of phenolphthalein indicator. Titrate back with a solution of nitric acid to the disappearance of the pink color of the solution. The amount of acid used subtracted from 10 cc. gives the number of cc. of sodium hydrate used in dissolving the yellow precipitate, which by using the factor weight, indicates the percentage of phosphorus.

DETERMINATION OF INSOLUBLE PHOSPHORUS.

The method is the same as described by Wm. S. Ferm.

SOLUTIONS.

Molybdate Solution.—Dissolve 200 grams of Merck's 100% pure, in a mixture of 800 cc. ammonium hydroxide (sp. gr. .90), and 200 cc. water. Pour this solution into a flask containing a solution of 1,375 cc. nitric acid and 1,275 cc. water. Let stand in a warm place over night. Filter, and it is ready for use.

Nitric Acid Solution.—11 cc. nitric acid to a liter of water.

Sodium Hydrate Solution.—About 8 grams of sodium hydrate to a liter of water.

DETERMINATION OF SILICA.

Dissolve 1 gram of the ore in about 50 cc. hydrochloric

acid, by boiling gently. Evaporate to dryness, and drive off all acid odor in order to thoroughly dehydrate the silica. Add water and a little hydrochloric acid; dissolve and filter, using a No. 9 cm. S.&S. filter paper. Wash the residue twice with hot dilute hydrochloric acid and three times with hot water to remove all traces of acid. Let stand for a short time and incinerate in a platinum crucible (average weight about 15 grams). A strong blast from a "Dangler" gasoline burner removes all carbon from the filter paper. Weigh. Moisten the contents with 2 or 3 drops of concentrated sulphuric acid and add from 5 to 10 drops of c.p. hydrofluoric acid. Volatilize, at a gentle heat, all silicon fluoride formed. When the crucible becomes dry, raise the temperature gradually until all sulphurous fumes are driven off. Now heat gradually over a blast lamp to a bright red, keeping this temperature for about five minutes. Cool in a desiccator and weigh. The difference in weight gives the amount of silica volatilized as silicon fluoride.

This process gives accurate results on the Gogebic ores when the percentage of insoluble lime, magnesia, and aluminum in the ore is not great enough to sensibly increase the weight of the residue after volatilizing by becoming transformed to sulphates.

Constant watching is necessary during the volatilizing of the silicon fluoride to prevent loss by spattering, for small drops may be thrown out if care is not taken.

The sodium carbonate fusion method is resorted to on silica determinations which cannot be safely analyzed by the hydrofluoric method.

On experimenting with sixteen samples of the Gogebic ores, the sodium carbonate fusion method showed an average of 6.01 percent. silica, while the hydrofluoric method averaged 6.04.

Manganese is determined by the regular Volhard's method. That is, adding zinc oxide to the chloride solution; boiling and titrating with potassium permanganate solution.

Alumina is determined as aluminum phosphate, a modification of the old Peters' method being used.

Lime is determined by the usual gravimetric method by weighing the precipitate (made by ammonium oxalate) as oxide of calcium.

Magnesia is determined as magnesium pyrophosphate in the usual manner.

DETERMINATION OF ORGANIC AND VOLATILE MATTER.

About one-half gram of ore is weighed into a platinum crucible and heated from one-half to one hour at a cherry red heat till the weights are constant. The loss of weight represents the organic and volatile portion.

STANDARDIZATION OF POTASSIUM DICHROMATE SOLUTION.

Weigh out $\frac{1}{2}$ gram of standard ore and prepare for titrating. Assume that the iron percentage has previously been determined as 62.30, and that the burette reading in this sample was 61.40 cc. We desire to take such a weight of the sample as will give a burette reading of 62.30 cc.; therefore $.5 : 61.40 :: x : 62.30$, or x equals .5073 grams. This weight of .5073 grams is used for all iron samples titrated with this solution.

The sodium hydrate solution is standardized, and the factor weight for phosphorus determination is found, in the same manner.

IX. METHODS USED AT THE LABORATORY OF THE CLEVELAND-CLIFFS IRON CO., ASHLAND MINE, IRONWOOD, MICH.

BY WM. S. FERM.

DETERMINATION OF IRON.

Weigh a factor weight sample (about .520 gram) of the ore into a $2\frac{1}{2}$ oz. beaker. Add 6 cc. stannous chloride; cover; put on the hot plate and boil until dissolved, which will take place in about a minute. Remove, washing the watch-glass and sides of the beaker into the solution. Complete the reduction with stannous chloride (the same solution as was used for dissolving the ore). Wash the contents into a beaker of 250 cc. capacity; add 40 cc. mercuric chloride solution and titrate with potassium bichromate solution, using as an indicator a weak solution of potassium ferricyanide.

SOLUTIONS.

Potassium Bichromate Solution.—Dissolve 159 grams of potassium bichromate with water in a 3,000 cc. flask by stirring or by agitating the solution with a jet of air from an air pipe. The air may be introduced into the solution by a rubber hose attached to the air pipe. When the potassium bichromate is dissolved, pour the solution into carboy (previously graduat-

ed with care to 35 liters) half full of water and fill to the 35 liter mark. Agitate until the solution is thoroughly mixed. Let stand for a day and standardize with 99.7% iron wire.

Stannous Chloride Solution.—154 grams of the salt dissolved in 2,500 cc. hydrochloric acid. The solution is added, to the ore in the beaker or to the solution in reducing, from a 100 cc. burette.

DETERMINATION OF SOLUBLE PHOSPHORUS.

Weigh 2 grams of the sample into a beaker; dissolve in 20 cc. hydrochloric acid and boil down to a syrup. Add 20 cc. of concentrated nitric acid and boil to about 10 cc. Remove watch-glass and wash down the sides of the beaker; dilute to about 25 cc. Filter through a rapid filter into a 250 cc. flask and wash twice, using as little water as possible. Add ammonia until the solution thickens. Clarify by adding nitric acid until the solution is of a pure amber color. Place the flask on the hot plate and bring to a temperature of 85°C., and add 40 cc. of molybdate solution; set on another plate which has been heated to 70°C., and let stand for about 3 minutes, when the precipitate will be settled. Filter while warm through a No. 2 F., 9 cm. filter. Wash the flask carefully and set aside to be used in the titration. Wash the filter twice with a dilute solution of nitric acid to remove any traces of iron, then fourteen times with distilled water. Into the flask, previously used, run 6 cc. standard sodium hydrate solution; remove the filter paper from the funnel and put into the flask; add about 50 cc. of warm water; stopper with a rubber stopper and shake vigorously to break up the paper and dissolve the precipitate; add a few drops of phenolphthalein indicator. If the phosphorus is less than .056 percent. the solution will become pink, if more, add enough of the sodium hydrate solution to a pink solution. Titrate back with standard nitric acid, adding drop by drop near the end reaction.

DETERMINATION OF INSOLUBLE PHOSPHORUS.

Ignite the silicious residue at a high temperature; cool, and put into a 6 oz. beaker. Add 10 cc. nitric acid and 25 cc. water. Place on a hot plate and bring to a boil; remove and filter. Heat the filtrate to 85°C. and add 15 cc. of molybdate solution and proceed in the regular manner for the determination of phosphorus.

SOLUTIONS.

Molybdate Solution.—(A.) 4,800 cc. water and 2,000 cc.

nitric acid. (B.) 1 pound molybdic acid dissolved in 1,200 cc. water and 700 cc. ammonia. When dissolved add 300 cc. nitric acid, with constant shaking. Cool. Add solution B. to A., pouring through a funnel with shaking after each slight addition and at the same time keeping cool.

Standard Sodium Hydrate Solution.—Dissolve 231 grams of sodium hydrate in 3 liters of water; add a saturated solution of barium hydrate to free the solution of sodium carbonate and stir until there is no further precipitation. Let stand for a few hours to settle. Siphon off the clear liquid; pour into a graduated carboy and fill to the 35 liter mark with distilled water. Agitate until well mixed.

Standard Nitric Acid Solution.—100 cc. nitric acid to 10,000 cc. water. Balance against the sodium hydrate solution.

Standardize with a pure yellow precipitate (ammonium phosphomolybdate) containing .00163 gram phosphorus.

DETERMINATION OF SILICA.

Dissolve 1 gram of ore in hydrochloric acid. Evaporate to dryness and redissolve in dilute hydrochloric acid. Filter on an ashless filter; wash; dry; ignite in a platinum crucible and weigh. Add a few drops each of hydrofluoric and sulphuric acid. Evaporate to dryness and the silica will pass off as silicon fluoride. Ignite and weigh. The difference between the two weights will be the weight of the silica, (SiO_2).

The insoluble silicious matter may contain calcium, magnesium, potassium, or sodium, and the loss in weight due to driving off the silica may not be entirely apparent, on account of the fact that some of the sulphuric acid will combine with the above named elements forming sulphates, consequently the amount of sulphuric acid so combining must be determined and added to the amount already found. This may be accomplished as follows:

Fuse the residue with sodium carbonate and dissolve in water acidulated with a little hydrochloric acid. Heat to boiling and add a hot solution of barium chloride. Filter; ignite and weigh the precipitated barium sulphate. The weight of the barium sulphate times .3433 give the amount of SO_3 , which should be added to the amount of silica already obtained. When the ore contains an appreciable amount of barium sulphate, this method is not admissible, as the SO_3 of the barium sulphate would appear as silicious matter.

DETERMINATION OF SULPHUR.

Fuse 1 gram of ore with 10 grams of sodium carbonate and 1 gram of potassium nitrate in a platinum crucible. Remove the mass from the crucible with hot water into a 250 cc. beaker; add 10 cc. hydrochloric acid; evaporate to dryness; dilute with hot water; bring to a boil and precipitate with one gram of barium chloride, adding the warm barium chloride solution to the filtrate. Set aside for a short time and the sulphur will precipitate almost immediately as barium sulphate. Filter and weigh. The weight of the sulphate times .13734 give the weight of the sulphur.

Manganese is determined by Volhard's method; adding zinc oxide to the chloride solution; boiling and titrating with permanganate solution.

Alumina is determined as aluminum phosphate.

Lime is determined by the gravimetric method—precipitating the calcium as calcium oxalate, igniting and weighing as CaO.

Magnesia is determined as magnesium pyrophosphate.

Organic and Volatile matter is determined by taking one gram of ore in a platinum crucible and heating at a cherry red heat until a constant weight is obtained. The loss in weight represents the organic and volatile matter.

**STANDARDIZATION OF POTASSIUM BICHROMATE SOLUTION
AND DETERMINATION OF FACTOR WEIGHT FOR THE
DETERMINATION OF IRON.**

Take a piece of iron wire (99.7% pure) about 6 in. long; cut in two near the middle; weigh each separately and place into an Erlenmeyer flask. Add 15 cc. hydrochloric acid and 15 cc. water; stopper with a rubber stopper with a small hole in it and boil slowly for 15 minutes, when the wire will be dissolved. Reduce with a few drops of stannous chloride solution, add 40 cc. mercuric chloride and titrate, using a weak solution of potassium ferricyanide (about .200 gram to 20 cc. water) as an indicator. Assuming the weights of the two pieces of wire as .2054 and .2396 grams respectively and the bichromate solution used in the titrations as 19.9 cc. and 23.3 cc. we have in the first case .2054 times .997 equals .20478 gram iron oxidized by 19. cc. of the bichromate solution; in the second titration we have 23.3 cc. of bichromate solution oxidizing .23888 gram of iron. From these results we find that 1 cc. of the bichromate solution to be equivalent to .01027

gram of iron, from which the factor weight may be easily calculated. Check by a determination on a standard ore.

X. METHODS USED AT THE LABORATORY OF THE BROTHER-
TON AND SUNDAY LAKE IRON MINING COMPANIES,
BROTHERTON AND SUNDAY LAKE MINES,
WAKEFIELD, MICHIGAN.

BY BURDETTE F. GRANT.

DETERMINATION OF IRON.

Dissolve the factor weight of the sample in a 4 oz. usual form beaker, with 25 cc. hydrochloric acid, by boiling. The hydrochloric acid used is of sp. gr. 1.20 diluted with one-eighth water to raise the boiling point of the solution, thereby increasing the chemical action. Also add 5 to 10 drops of stannous chloride which hastens solution of the ore. After the ore is dissolved, as shown by a white residue, add carefully drop by drop stannous chloride solution to the hot solution (stirring at the time) until the ferric solution becomes a colorless ferrous solution. Wash down the sides of the beaker and watch-glass into a 500 cc. beaker and dilute to about 400 cc. Add 10 to 20 cc. of saturated mercuric chloride solution all at once and stir. The mercuric chloride is reduced to insoluble mercurous chloride, a white precipitate often silky, by the excess of stannous chloride which is converted into stannic chloride. If there should be too great an excess of stannous chloride the mercuric chloride is further reduced, gray metallic mercury being thrown down which renders the titration unreliable. Titrate immediately with potassium bichromate solution to the end of any blue color on the addition of a drop of the solution to a drop of potassium ferricyanide indicator on the spot plate. The solutions should be titrated at the same temperature and to the same color as adopted in a determination on standard ore. A sample of standard ore is run with the samples being tested, which will check the work. A factor weight of the sample is taken so that the percent of iron can be read direct from the burette.

SOLUTIONS.

Stannous Chloride Solution.— $\frac{1}{2}$ pound of stannous chloride, 600 cc. water and 400 cc. hydrochloric acid. Boil

until the solution is clear; add a little metallic tin to prevent the formation of oxides.

Potassium Bichromate Solution.—4.39 grams of the salt to a liter of water. A carboy of bichromate solution of this strength is made and after thoroughly mixing is allowed to stand for a day or two before standardizing.

Ferricyanide Solution (Indicator).—One gram of potassium ferricyanide crystals dissolved in 100 cc. water. Five cc. of this solution is diluted with 50 cc. water. The stronger solution is used first in the titration, the weaker being used for the final reaction as it is more delicate.

Note.—We prefer the bichromate to the permanganate method because of the inconstancy of strength of potassium permanganate solution.

DETERMINATION OF PHOSPHORUS.

The method used is based on the insolubility of yellow ammonium phospho-molybdate in a solution containing nitric acid, water and ammonium nitrate, being least soluble in ammonium nitrate.

Dissolve the factor weight of the sample (about 2.4 grams) in a covered 8 oz. Griffin beaker with 50 cc. of strong hydrochloric acid diluted with one-eighth water (see iron). Boil vigorously to a syrup and drive off all the hydrochloric acid possible without burning the contents of the beaker. There being no organic matter present, and the iron found to be thoroughly oxidized we do not need to add any nitric acid at this point. The only other advantage of using nitric acid would be the forming of chloronitric acid which would escape as a gas or vapor, thus eliminating all the hydrochloric acid. The objections would be: the increase in time spent, bumping caused by the nitric acid, and the insoluble precipitate which sometimes appears when adding nitric acid, as ferric oxide is insoluble in that acid, and this precipitate is too fine to be filtered. Wash the cover glass into the beaker also washing down the inside of the beaker. Filter and wash thoroughly, obtaining about 60 cc. of filtrate in an 8 oz. Erlenmeyer flask. Add a few drops of nitric acid. Add ammonium hydrate until the solution becomes a straw color and a slight precipitate forms, which disappears on warming, and the solution becomes a rich amber color. Heat to not more than 85°C. The solution should not be strongly acid with hydrochloric acid as the phosphorus precipitate does not form as rapidly or as completely in

a hydrochloric as in a nitric solution. The solution should be nearly neutral as the precipitate will not come down readily in a very acid solution.

Add 25 cc. sensitized molybdic acid solution and the phosphorus will come down at once. Shake and let stand to settle. Filter and wash at least five times with a weak solution of nitric acid to remove all iron which would appear as phosphorus. Wash with a weak solution of potassium nitrate and once with water. Place the filter paper containing the precipitate in the flask in which the precipitation was made, first thoroughly rinsing the same. Add 30 cc. water and 10 cc. of standard sodium hydrate solution and shake until the filter paper is broken up and the precipitate dissolved. Add five drops of phenolphthalein solution and titrate with standard nitric acid solution. The difference between the number of cc. of standard alkali and acid used gives the number of cc. of sodium hydrate used in dissolving the yellow precipitate and which indicates the percentage of phosphorus, when a factor weight of the sample is taken.

SOLUTIONS.

Molybdate Solution.—(A.) 100 grams molybdic anhydride (Merck's pure), 400 cc. cold water and 85 cc. ammonium hydrate; filter.

(B.) 390 cc. nitric acid and 625 cc. water. Add solution A. to B., keeping the solution cold and stirring. Dissolve .025 gram sodium ammonium phosphate in water and add to the solution. This produces a yellow precipitate which clarifies the solution. Let settle and filter. In making up this solution we use a smaller amount of acid and more ammonia and water than is usually taken, which with the addition of the sodium ammonium phosphate sensitizes the solution. 25 cc. of the molybdate solution is sufficient to precipitate .650 percent of phosphorus. It might be thought that when we have a sample running .30 percent or less a smaller amount of the molybdate solution could be used thereby affecting a saving in molybdic acid, the most expensive re-agent we use in our routine work, but experience has shown that we cannot do so and get reliable results.

Nitric Acid Solution.—13 cc. of strong nitric acid to a liter of water.

Potassium Nitrate Solution.—1 gram of the salt to a liter of water.

Standard Sodium Hydrate Solution.—To 100 grams of sodium hydrate add enough water to dissolve and pour into a tall 500 cc. cylinder. Add a little barium hydrate to precipitate any sodium carbonate present. Allow to settle, and siphon off the clear liquid and dilute in proportion 30 cc. to two liters of water. Make a carboy half full. Titrate against the standard nitric acid solution, making one cc. of the alkali equivalent to one of the acid.

Standard Nitric Acid Solution.—20 cc. nitric acid (sp. gr. 1.20) to 2 liters of water.

XI. METHODS USED AT THE LABORATORY OF CORRIGAN, McKINNEY & COMPANY, COLBY AND IRONTON, MINES, BESSEMER, MICH.

DETERMINATION OF IRON.

The method used is the same as described by R. S. Brown.

DETERMINATION OF PHOSPHORUS.

Weigh 3 grams of the ore into a 250 cc. Griffin beaker; treat with 5 to 6 cc. stannous chloride solution and 20 cc. hydrochloric acid, boiling until dissolved. Oxidize with a few drops of nitric acid, continuing the boiling for a few minutes. Dilute and filter, using a 11 cm. No. 1 Munktell filter paper, washing with water, into a 550 cc. Erlenmeyer flask. Add ammonia in excess and neutralize with nitric acid, obtaining a clear solution. Heat to 80°C. and add 30 cc. molybdic acid solution and agitate by whirling the flask six or seven times. When the precipitate has settled, filter, the same as described above, and wash five times with a solution of 15 cc. ammonia, and 25 cc. sulphuric acid to a liter of water. Introduce 7 grams of 20 mesh zinc into the flask previously used, and place the funnel containing the yellow precipitate in the neck of the same; wash twice with a solution of (1:3) ammonia and water, thereby dissolving the precipitate; wash twice with water. Add 75 cc. solution (1:4) of sulphuric acid and water. Let stand for 5 or 10 minutes, then heat. A green color indicates the end reaction, when the reduction is complete. Filter off the excess of zinc on an 18½ cm. S. & S. No. 588 folded filter, washing flask and filter once. Titrate with standard potassium permanganate solution used in iron determination.

Percent. of phosphorus equals .00271 times number of cc.

permanganate solution used if one cc. is equivalent to 1% iron when a half gram sample is taken.

INSOLUBLE PHOSPHORUS.

The ore at the Colby mine contains about .002% of insoluble phosphorus, to determine which we proceed as follows:

Fuse the insoluble residue remaining on filter after the first filtration with about 5 times its volume of sodium carbonate, after fusion remove crucible and hold in an inclined position until the mass solidifies. When cool gently roll the crucible between the hands and allow the fused mass to fall into a 200 cc. evaporating dish; add cold water, acidulate with hydrochloric acid, and evaporate to dryness. Cool, moisten with hydrochloric acid and evaporate a second time. Take up with hydrochloric acid and water; heat; filter, washing with hot water and warm dilute hydrochloric acid, and proceed as for soluble phosphorus.

SOLUTIONS.

Molybdic Acid Solution.—500 grams of molybdic acid, to 2,000 cc. water and 500 cc. ammonia. Shake until the acid is in solution, cool, and add slowly, with stirring, to a cold mixture of 2,000 cc. nitric acid and 3,000 cc. water.

Standard Potassium Permanganate Solution.—128 grams of the salt dissolved in warm water and diluted to about 45 liters, of such a strength that 1 cc. is equivalent to 1% iron when a half gram sample is taken.

DETERMINATION OF MANGANESE.

The method is the same as described by R. S. Brown, with the following exception: Add 3 to 4 cc. stannous chloride solution with the hydrochloric acid to the ore in the beaker.

Note.—Run a blank occasionally and subtract the amount of permanganate used from that used when a sample is analyzed.

DETERMINATION OF SILICA.

The method used is essentially the same as described by C. J. Mott except that the insoluble residue from the phosphorus determination is used instead of a sample of the ore.

DETERMINATION OF ALUMINA.

With the following exceptions, the method is the same as described by R. S. Brown. To the cool acid solution add 2

grams of sodium phosphate in solution, instead of 3 to 4 cc. of saturated solution of sodium ammonium phosphate. Sodium hyposulphite solution is added before acetic acid.

DETERMINATION OF SULPHUR.

Weigh 2 grams of ore into a 250 cc. beaker and dissolve in hydrochloric acid; add 2 to 3 cc. nitric acid and evaporate to dryness. Add hydrochloric acid and evaporate to dryness a second time. Take up with a small amount of hydrochloric acid, dilute and filter into a 16 oz. flask, washing the filter twice. Add about 3 cc. concentrated solution of barium chloride and set on hot plate until the barium sulphate has nearly all come down; remove and let settle. Filter on a No. 2 F Munktell filter paper, washing with warm dilute (1:10) hydrochloric acid and with hot water. Ignite in a platinum crucible and weigh as BaSO_4 .

DETERMINATION OF LIME AND MAGNESIA.

Weigh 1 gram of ore into a beaker; dissolve in hydrochloric acid and evaporate to dryness twice. Take up with hydrochloric acid, dilute, filter and wash with water. Burn the filter paper and fuse the residue with sodium carbonate; remove from flame and hold in an inclined position until the fused mass solidifies. Place in an evaporating dish, cool, and add a little water from wash bottle. When sufficiently cool roll gently between the hands, permitting the fused mass to drop into the evaporating dish; add water and acidulate with hydrochloric acid; evaporate to dryness, cool, moisten with hydrochloric acid and evaporate a second time. Take up with hydrochloric acid and hot water, and filter into the first filtrate. Precipitate with ammonia and boil. Filter through a large filter. Redissolve the precipitate, re-precipitate with ammonia, and filter. Unite the filtrates, add ammonium oxalate and ammonia, and boil. Filter on an ashless filter; ignite and weigh as CaO .

MAGNESIA.

To the filtrate from the calcium oxalate filtration, add one-third its volume of ammonia and from 2 to 4 cc. of strong solution of microcosmic salt; stir and set in a cool place for 12 to 24 hours. Filter on an ashless filter, wash with a solution of (1:2) ammonia; introduce the filter paper into a porcelain crucible; burn the carbon off slowly and weigh as $\text{Mg}_2\text{P}_2\text{O}_7$.

XII. METHODS USED AT THE LABORATORY OF THE OLIVER IRON MINING COMPANY, IRON RIVER, MICH.

By W. J. PHILLIPS.

DETERMINATION OF IRON.

Weigh .5 gram of ore into a No. 0 beaker; add about 2 cc. stannous chloride and 5 cc. concentrated hydrochloric acid; cover the beaker with a watch-glass and set on a hot plate; digest at a temperature just short of boiling until all the iron is dissolved. Reduce to the ferrous condition with stannous chloride solution and allow to cool. Dilute the solution to about 250 cc.; add about 10 cc. of a saturated solution of mercuric chloride and about 20 cc. of titrating solution. Titrate at once with standard potassium permanganate solution until the last drop gives a pink color.

SOLUTIONS.

Stannous Chloride Solution.—100 grams of the salt dissolved in 500 cc hydrochloric acid and 500 cc. water.

Standard Potassium Permanganate.—4.4 grams potassium permanganate crystals to a liter of water. One cc. of this solution is equivalent to 1.5 percent. of iron when a .5 gram sample is taken.

TITRATING SOLUTION.

A. 160 grams manganese sulphate to 260 cc. water.

B. 330 cc. phosphoric acid to 370 cc. water.

C. 320 cc. sulphuric acid to 480 cc. water.

Make the three separate solutions and when cool mix.

DETERMINATION OF PHOSPHORUS.

Weigh 1 to 5 grams of ore (according to the amount of phosphorus), into a No. 3 beaker and add 25 cc. concentrated hydrochloric acid. Boil until all the iron is dissolved; add a few drops of nitric acid and evaporate to about 10 cc. Dilute with water and filter into a 16 oz. flask. If the ore contains insoluble phosphorus, fuse the insoluble residue with sodium carbonate; dissolve in water and a little hydrochloric acid; evaporate to dryness; redissolve in water, add a few drops of hydrochloric acid and filter into the first filtrate. Now add ammonium hydrate until ferric hydrate separates and the mass becomes thick. Then add strong nitric acid until the precipitate redissolves and the liquid has a clear amber color, not the least red. Heat to 60°C. and add 40 cc. molybdic acid solu-

tion. Shake for about five minutes and allow to settle for one hour. Filter through a No. 0, 11 cm. Munktell filter; wash flask and filter paper three times with ammonium sulphate solution. Put 10 grams powdered zinc into the flask and place the funnel containing the yellow precipitate back in the flask and dissolve with (1:3) ammonia, not more than 20 cc. Add 75 cc. (1:4) sulphuric acid. Let stand until the solution assumes a green color, then set on hot plate until it turns a clear transparent green. Filter through glass wool and titrate with potassium permanganate, as used for the iron determination.

In using this process it is well to check results from time to time with a standard ore in which the phosphorus has been determined gravimetrically.

SOLUTIONS.

Ammonium Sulphate Solution.—10 cc. ammonia, 970 cc. water, and 20 cc. sulphuric acid.

Molybdic Acid Solution.—Dissolve 300 grams molybdic acid in 1,200 cc. ammonia (sp. gr. .96); filter and add to 4,500 cc. nitric acid (sp. gr. 1.20).

XIII. METHODS USED AT THE LABORATORY OF THE CRYSTAL FALLS IRON MINING CO., CRYSTAL FALLS. MICH.

BY PHILIP SHAW.

The permanganate method is used in the determination of iron.

DETERMINATION OF PHOSPHORUS.

For high phosphorus the Emmerton method is used and for low phosphorus the Handy method.

Manganese is determined by Volhard's method and Peters' method is used for alumina.

DETERMINATION OF SULPHUR.

Dissolve the ore in hydrochloric acid after mixing with an equal quantity of potassium chlorate. Evaporate and bake hard. Take up with (1:1) hydrochloric acid, filter and proceed to determine as BaSO_4 .

For silica, lime and mangnesia the usual gravimetric methods are employed, all being described in Blair.

XIV. METHODS USED IN THE LABORATORY OF THE FLORENCE
IRON RIVER CO., FLORENCE, WISCONSIN.

BY KARL J. JOHNSON.

DETERMINATION OF IRON.

Weigh a factor weight sample of the ore into a small beaker; add $2\frac{1}{2}$ cc. of stannous chloride solution and 30 cc. of (1:1) hydrochloric acid solution; cover and heat until dissolved. (If an excess of stannous chloride was added reduce by oxidizing with permanganate solution). When dissolved carefully reduce with stannous chloride; add 20 cc. of saturated mercuric chloride solution; and add to 150 cc. warm water and 10 cc. manganous sulphate solution in a 350 cc. casserole, and titrate with potassium permanganate solution. The burette reading gives directly the percentage of metallic iron.

SOLUTIONS.

Stannous Chloride Solution.—160 grams of the salt to 720 cc. distilled water and 360 cc. strong hydrochloric acid, with addition of heat.

Manganous Sulphate Solution.—Dissolve 80 grams of the salt in 875 cc. of water; add 165 cc. of phosphoric acid (sp. gr. 1.7) and 160 cc. of concentrated sulphuric acid.

Potassium Permanganate Solution.—Weigh 116 grams of the salt into a No. 6 beaker; add about 800 cc. of water and boil steadily for two hours to oxidize all organic matter present. Dilute to 40 liters with distilled, filtered water.

Note.—Light will have no effect on solution made up in this way.

Standardization of the Permanganate Solution.—Dissolve about 0.3 gram of fine iron wire in dilute sulphuric acid, adding about $\frac{1}{4}$ gram of pure sodium carbonate to keep all the iron in solution. Titrate directly against the permanganate solution and calculate the factor weight so that 1 cc. of the solution is equivalent to 1% iron.

DETERMINATION OF PHOSPHORUS.

Dissolve 3 grams of the ore sample in strong hydrochloric acid; evaporate to about 5 cc.; dilute with water and filter.

Should the residue retain some of the phosphorus, burn off the paper containing the residue in a platinum crucible; increase the heat to the highest temperature of the laboratory lamp for 2 to 3 minutes; cool; fill the crucible half full of dilute hydro-

chloric acid, boil for two minutes and add to the main filtrate.

Add 18 cc. of ammonia; dissolve the precipitate formed with nitric acid, and add 30 cc. of molybdate solution. If quick analysis is desired, shake for 5 minutes and filter at once. If not let stand for two hours; filter, wash the precipitate with 2% nitric acid, and finally with cold water. Dissolve the precipitate from filter paper into the flask with (1:2) ammonia, washing the filter with water. Add 10 grams of mossy zinc (c.p.), 75 cc. water and slowly 15 cc. of strong sulphuric acid. Boil for 15 minutes; filter through cotton; wash with water and titrate with the permanganate solution used for iron determination.

The factor weight for iron times 1.63 times the cc. of permanganate solution used in the titration divided by the number of grams of ore used gives the phosphorus value.

SOLUTIONS.

Molybdate Solution.—Dissolve one pound of molybdic acid in a mixture of 930 cc. of ammonia and 930 cc. of water. When dissolved pour slowly into a mixture of 2,250 cc. Nitric acid and 3,550 cc. of distilled water.

DETERMINATION OF SILICA.

Dissolve one gram of ore in hydrochloric acid; add a few drops of nitric acid and evaporate to dryness. Take up with hydrochloric acid and again evaporate to dryness. Re-dissolve in 10 cc. hydrochloric acid and 30 cc. water and filter into a No. 4 beaker saving the filtrate for the determination of alumina. Wash residue on filter with water, then with a weak solution of hydrochloric acid. Burn off the filter paper in a platinum crucible. Increase the heat to the highest temperature of the laboratory blast lamp for 2 to 3 minutes. Cool; fill the crucible half full of dilute hydrochloric acid and boil for two minutes and filter on an ashless filter into the filtrate saved for the alumina determination, washing with hot water. Ignite and weigh as silica.

DETERMINATION OF ALUMINA.

Dilute the filtrate obtained in the silica determination, to about 400 cc, with cold water. Add ammonia until the solution becomes a dark red color, being careful not to add an excess which will cause a precipitate. Then add 3 cc. hydrochloric acid and 2 grams of sodium phosphate (dissolved in water and filtered). Stir until the precipitate formed, is dissolved and the solution again becomes clear. Add 10 grams of hypo-sulphite of sodium (previously dissolved in water) and 15 cc. acetic

acid. (4 cc. of glacial acetic acid to 11 cc. water). Boil for 15 minutes, and filter as rapidly as possible on an ashless filter, washing thoroughly with hot water. Dry; ignite carefully in a porcelain crucible and weigh as aluminum phosphate (AlPO_4).

DETERMINATION OF MANGANESE.

Weigh a one gram sample into a No. 2 beaker. Dissolve in hydrochloric acid; evaporate nearly to dryness and add 25 cc. of strong nitric acid. Evaporate until a film forms on the surface; again add 25 cc. nitric acid; heat to boiling and add slowly from 1 to 2 grams of potassium chlorate. Cool, dilute with a little water, filter and wash twice with water. Introduce the filter and contents into the beaker previously used and add 25 cc. of ferrous ammonium sulphate solution which by stirring will dissolve the manganese dioxide. Titrate the excess of ferrous ammonium sulphate with permanganate solution. Also titrate a blank of 25 cc. of the sulphate solution. The difference between the two results gives the amount of sulphate solution used in dissolving the manganese dioxide.

The factor weight for iron times 49.1 times the number of cc. of permanganate solution used gives the manganese.

DETERMINATION OF LIME.

Weigh out one gram of ore; dissolve in hydrochloric acid and add a few drops of nitric acid. Evaporate to dryness; re-dissolve in hydrochloric acid and again evaporate to dryness. Take up with 10 cc. hydrochloric acid and 30 cc. water; filter and wash with water, saving the filtrate. Ignite in a platinum crucible, and fuse the residue with pure sodium carbonate. Dissolve with water and a few drops of hydrochloric acid; evaporate to dryness and re-dissolve with 5 cc. of hydrochloric acid and 15 cc. of water. Filter into the main filtrate; add a few drops of bromine water and an excess of ammonia. Boil off part of the ammonia, filter and wash well with hot water. Evaporate to about 100 cc. and add 15 cc. of saturated solution of ammonium oxalate, and add ammonia in excess. Boil for a few minutes, allow to settle; filter on an ashless filter, (saving the filtrate for the determination of magnesia); ignite and weigh as CaO .

DETERMINATION OF MAGNESIA.

To the filtrate obtained in the lime determination, add 15 cc. of concentrated solution of sodium ammonium phosphate,

then ammonia to increase volume one-third. Cool, stir several times, and let stand in a cool place for a few hours. Filter, washing with water containing one-third ammonia and 100 grams of ammonium nitrate to the liter. Ignite carefully and weigh.

Dissolve the residue in a little water to which a few drops of hydrochloric acid have been added. Filter on an ashless filter, dry, ignite and again weigh.

The difference in the weights times 0.3621 gives the magnesia.

DETERMINATION OF SULPHUR.

Weigh one gram of ore into a No. 2 beaker; add 20 cc. of aqua regia and cover with a watch-glass. After the evolution of brown fumes has ceased evaporate to dryness using a gentle heat. Re-dissolve in hydrochloric acid and add 100 cc. water. Cool, add an excess of ammonia and heat to boiling with constant stirring. Allow to settle, filter and wash thoroughly with hot water. Evaporate the filtrate to about 150 cc., acidify with hydrochloric acid, heat to boiling and add slowly with stirring, 10 cc. boiling barium chloride solution, (100 grams of barium chloride to a liter of water). Let stand in a warm place for four hours. Filter, wash thoroughly with boiling water; ignite and weigh as BaSO_4 .

(The above method is a modification of that for the determination of sulphur in pyrites, published in Treadwell & Hall's text-book on Analytical Chemistry, 1905 edition).

DETERMINATION OF ORGANIC AND VOLATILE MATTER.

Weigh one gram of ore in a platinum crucible, heat over laboratory lamp from 3 to 4 minutes. Cool and weigh. The difference in weight represents the organic and volatile matter.

XV. METHODS USED AT THE LABORATORY OF THE COMMONWEALTH IRON COMPANY, COMMONWEALTH, WIS.

BY FRED G. CRAM.

DETERMINATION OF IRON.

One-half gram of the sample is weighed into a No. 1 beaker and heated with from 5 to 7 cc. of concentrated hydrochloric acid. When dissolved the iron is reduced from the ferric to the ferrous condition with stannous chloride. The

stannous chloride is run in a fine stream into the beaker containing the dissolved sample, with constant stirring, until the solution becomes colorless. The cover glass and the inside of the beaker are washed down with a fine stream of water, about as much water being used as there is solution, and set aside to cool. When cool, 25 cc. mercuric chloride are added. The solution is now washed from the beaker into about 200 cc. of water and 15 cc. of titrating solution added. It is now titrated with potassium permanganate.

SOLUTIONS.

Stannous Chloride.—85 grams of the salt are dissolved in 50 cc. of water and 50 cc. of hydrochloric acid, boiled and diluted to a liter. This solution is kept in a flask like an ordinary wash-bottle.

Mercuric Chloride.—A saturated solution.

Titrating Solution.—160 grams of manganese sulphate crystals are dissolved in 1,750 cc. of water; and 330 cc. of phosphoric acid (sp. gr. 1.7) are added. After mixing, 320 cc. of sulphuric acid (sp. gr. 1.84) are added slowly, to prevent heating.

Potassium Permanganate of such strength that 1 cc. is equivalent to 1 percent. when a half-gram sample is taken.

DETERMINATION OF MANGANESE.

Volhard's method is used.

One and a half grams of ore are weighed into a No. 1 lipped beaker and dissolved in 15 cc. hydrochloric acid. When the solution is complete, a few drops of bromine water are added and with covers removed the beaker set on a hot plate to evaporate the excess of acid. When the solution is reduced to about 5 cc., the beaker is removed from the hot plate and a solution of sodium carbonate added, a little at a time, until the small clots of the precipitate dissolve quite slowly and the liquid is of a dark red color. The solution, now free from any precipitate, is washed into a graduated mixing cylinder of 500 cc. capacity and made up to about 150 cc. A small quantity of an emulsion of zinc oxide is added and the cylinder shaken vigorously; another small amount is added and the cylinder shaken again. If now on standing for a minute, a scum of zinc oxide forms enough has been added. Sometimes three additions of the oxide are necessary. The solution is now made up to 300 cc. with water and shaken vigorously for half a minute; then

transferred to a tall beaker of 300 cc. capacity and the precipitate allowed to settle, which takes place generally within half an hour. 100 cc. of the slightly milky supernatant liquid are drawn off with a pipette into a 12 oz. Erlenmeyer flask, one drop of the zinc oxide emulsion added and the flask set on the hot plate. When heated to nearly boiling it is titrated with potassium permanganate. After each addition of the permanganate a stopper is inserted and the flask shaken. The precipitated manganese dioxide settles quickly and the titration may proceed. Should the solution become cloudy with fine particles of the dioxide, heat again. Titrate till one drop of the permanganate tinges the solution pink.

The potassium permanganate solution is standardized by a standard ore determination and its manganese value figured, .2496 times the iron factor being the value in manganese. The solution is made up of such strength so that 1 cc. is equivalent to one-tenth percent of manganese.

DETERMINATION OF PHOSPHORUS AND SILICA.

The methods used at the Aragon mine laboratory, Norway, Mich., are used.

DETERMINATION OF ALUMINA, LIME AND MAGNESIA.

The methods given in the second edition of Blair's "Chemical Analysis of Iron," are used, the Peter's method being used for alumina.

In our every day work but two substances are determined—iron and manganese.

XVI. METHODS USED AT THE LABORATORY OF THE OLIVER IRON MINING CO., CHAPIN MINE, IRON MOUNTAIN,, MICH.

By J. H. HITCHENS.

DETERMINATION OF IRON.

The Zimmerman-Reinhardt method is used.

About .5 gram (according to the strength of the permanganate solution) of the pulp, having been dried at 212°F. and passed through a 100 mesh sieve, is weighed and placed in a 100 cc. lipless beaker, and about 20 cc. strong hydrochloric acid + 2% stannous chloride solution added; then covered; placed upon a hot plate (which is heated by two Dangler gaso-

line burners) and dissolved. When dissolved it is reduced by a stannous chloride solution contained in a 500 cc. separatory funnel attached to the wall by a clamp and in close proximity to the hot plate. The inside of the beaker is then washed down and the solution allowed to cool. When cold, about 5 cc. mercuric chloride solution are added; and after allowing the solution to thoroughly precipitate, about 20 cc. manganese sulphate solution are added, the solution washed into a 350 Griffin beaker, diluted to about 300 cc. and titrated with a standard potassium permanganate solution, one cc. of which corresponds to one percent of iron.

SOLUTIONS.

Potassium Permanganate Solution.—About 3 grams to a liter of water.

Mercuric Chloride Solution.—A saturated solution.

Stannous Chloride Solution.—About 2 liters of concentrated stannous chloride are made by dissolving pure feathered tin in warm hydrochloric acid until a saturated solution is obtained. About 45 cc. of this solution is mixed with 450 cc. water and poured into the separatory funnel.

Manganese Sulphate Solution.—5 lbs. manganese sulphate, 2,500 cc. water, 4,675 cc. phosphoric acid, and 4,500 cc. sulphuric acid.

DETERMINATION OF PHOSPHORUS.

Two grams (one gram if time is limited) of ore are weighed into a 150 cc. Griffin beaker and dissolved with 35 cc. of strong hydrochloric acid; after which it is evaporated to a syrupy mass. It is then filtered into an 8 oz. Erlenmeyer flask and after the filter (previously moistened with dilute hydrochloric acid) has been thoroughly washed with hot distilled water, the flask is removed and ammonium hydrate added, precipitating the iron which is redissolved by the careful addition of nitric acid. At the proper temperature about 25 cc. of ammonium molybdate solution are added and after shaking the precipitate is allowed to settle; after which it is filtered through a 9 cm. filter; washed with water until all traces of acid are removed and returned to the thoroughly rinsed flask for titration. 40 cc. of sodium hydrate solution are added, the flask closed with a rubber stopper and shaken until the precipitate is dissolved. The stopper is removed and the inside of the flask washed down with distilled water. Two drops of

phenolphthalein solution are added and the solution titrated with nitric acid solution until the color disappears.

SOLUTIONS.

Sodium Hydrate Solution.—This is made of such strength that 1 cc. is equivalent to .002 percent phosphorus when a 2 gram sample is taken.

Nitric Acid Solution.—This solution is made so that 1 cc. is equivalent to 1 cc. of the sodium hydrate solution.

Molybdate Solution.—Wood's formula. One pound of Merck's molybdic acid, 85% pure, is mixed with 1,200 cc. water and 700 cc. ammonia (sp. gr. .90) added and the mixture shaken until the acid is dissolved. 300 cc. nitric acid (sp. gr. 1.42) are now carefully added with a vigorous shaking of the solution after each slight addition. Into each of four three liter bottles pour 1,200 cc. and add 500 cc. nitric acid. To each add, with constant shaking to prevent precipitation, 550 cc. of the molybdic acid solution. Filter if necessary. In practice but one bottle is made up at a time, the remainder of the molybdic solution being kept in a tightly stoppered bottle until required.

Phenolphthalein Solution.— $\frac{1}{2}$ gram dissolved in 50 cc. alcohol and diluted to 100 cc. with distilled water.

DETERMINATION OF SILICA.

There being no soluble silica and only a trace of insoluble phosphorus in our ores, the insoluble residue in the phosphorus is used. The filter and its contents are allowed to dry, (sometimes ignited while wet), ignited, and after cooling somewhat is placed in a dessicator until cold. It is then weighed and the silica estimated from the insoluble residue.

This method has proven almost unvarying in Chapin ores, but recourse to the alkaline carbonate fusion and to the hydrofluoric acid volatilization methods is kept up as a check.

DETERMINATION OF MANGANESE.

The method used is essentially that of Volhard's. (See third edition, Blair, page 48.)

DETERMINATION OF MOISTURE.

Moisture is taken with a Fairbanks moisture balance, which both weighs and gives the percentage of loss up to 50 ozs. or 100%. (See cut 246, page 19, E. H. Sargent & Co.'s catalogue, 1905).

**XVII. METHODS USED AT THE LABORATORY OF THE OLIVER
IRON MINING CO., ARAGON MINE, NORWAY, MICH.**

BY GUSTAF A. HELLBERG.

DETERMINATION OF IRON.

The method used is the same as described by Edward A. Separk.

DETERMINATION OF PHOSPHORUS.

A gravimetric process, with the direct weighing of the phospho-molybdate, described in Blair's "Chemical Analysis of Iron," second edition, pages 102-103, is used.

For the determination of silica the old sodium carbonate fusion method is followed.

Lime is determined by the usual gravimetric method and magnesia, as magnesium pyro-phosphate in the usual manner.

In the determination of sulphur the method described in Blair, pages 220 to 221, second edition, is followed.

Volhard's method is used in the determination of manganese and Wohler's method for alumina, described on pages 112 and 242 of Blair.

**XVIII. METHODS USED IN THE LABORATORY OF THE PENN
IRON MINING COMPANY, VULCAN, MICHIGAN.**

BY F. A. JANSON.

DETERMINATION OF IRON.

Dissolve .5 gram of ore in a No. 1 beaker, without lip, using 30 cc. hydrochloric acid, covering with watch-glass and boiling gently until in solution. Remove cover and add stannous chloride solution from a burette, until the solution becomes colorless. Pour into a liter glass jar or beaker containing the following mixture:—about 600 cc. pure cold water, 50 cc. mercuric chloride solution and 25 cc. "titrating solution", thoroughly mixed. Carefully wash the small beaker. Titrate with potassium permanganate solution until, with the addition of one drop, the solution becomes pink. The percentage of iron in the ore will be equal to the number of cc. permanganate solution used, multiplied by the percentage value of 1 cc.

SOLUTIONS.

Potassium Permanganate Solution.—Dissolve 42.3 grams of the salt in a four liter flask two-thirds full of pure water. Make up to 10,200 cc. Titrate with a standard ore and calculate the amount of water to add so that 1 cc. equals 1 percent of iron. Add the required water, shake well and titrate again another standard. If 1 cc. does not equal 1 percent of iron, calculate the factor value for 1 cc. of the permanganate and use such in the determinations.

Stannous Chloride Solution.—160 grams of the salt to a liter of water and a liter of hydrochloric acid, with the addition of some feathered tin.

Mercuric Chloride.—A saturated solution.

Titration Solution.—Dissolve on the sand bath 200 grams of manganous sulphate in 1,000 cc. water and add a few cc. of sulphuric acid. In a four liter flask put 1,200 cc. water, add very slowly 400 cc. sulphuric acid and 430 cc. phosphoric acid (sp. gr. 1.70). When both solutions are cool add the manganous sulphate solution to the acid solution and mix thoroughly.

BICHROMATE METHOD.

The method is the same as described by Fred Anderson.

DETERMINATION OF PHOSPHORUS.

Dissolve 1.63 grams of the ore in about 25 cc. hydrochloric acid, and evaporate to dryness. Add 8 to 10 cc. nitric acid; cover and heat until all is in solution. Dilute with water, to save filter, and filter into a No. 2 Griffin beaker, rinsing out the beaker well with a fine jet of water and washing the paper twice. Stir the contents of the beaker and evaporate to about 15 cc. While still hot add 15 cc. freshly filtered molybdic acid solution and stir well with a rubber tipped glass rod, without touching the sides and bottom of the beaker. Let stand from one to two hours until the precipitate has settled, leaving the solution clear. Siphon off the clear liquid and filter on a Munktell No. 1F 7 cm. filter, which has been previously dried at 100°C. and weighed. Wash the beaker carefully and if any precipitate adheres, use a rubber policeman to detach. Wash paper four or five times with 1% nitric acid solution. Remove the filter and dry in a hot air bath at 100°C. When perfectly dry, weigh and each milligram of the precipitate will correspond to .001% of phosphorus.

A MORE RAPID METHOD FOR PHOSPHORUS.

Dissolve 1.63 grams of ore in 25 cc. hydrochloric acid and evaporate to a syrup; add 8 to 10 cc. nitric acid; cover and boil until most of the brown fumes are driven off. Dilute with water and filter into a 300 cc. Erlenmeyer flask. Add ammonia until thick; neutralize by adding nitric acid until the solution assumes a straw color. While still hot add 20 cc. molybdate solution. Stopper and shake vigorously for a minute. Let stand for one-half hour, then proceed as in the previous method.

SOLUTIONS.

Molybdate Solution.—(A.) Dissolve 225 grams of molybdic acid in 475 cc. water and 475 cc. ammonia, in a two liter flask.

(B.) Add 1,340 cc. nitric acid to 1,475 cc. water.

When both mixtures are cool add A. to B. slowly, shaking well after each addition. Keep in a cool, dark place. Filter each day before using.

REMARKS.

In addition to the two above described methods, for the determination of phosphorus the "Handy method" described in "Chemical and Metallurgical Hand Book" by Cremer & Bicknell, is occasionally used. When using this method, we take a three gram sample and make the standard solution of sodium hydrate of such strength that 1 cc. corresponds to .003% phosphorus.

XIX. METHODS USED AT THE LABORATORY OF THE LORETTO IRON COMPANY, LORETTO, MICH.

By LEONARD C. DAVID.

DETERMINATION OF IRON.

One gram of the ore, powdered to pass through a 100 mesh sieve and dried at 100°C., is placed in a 60 cc. beaker. Add 5 cc. stannous chloride solution and 30 cc. hydrochloric acid; cover with a watch-glass and heat on the hot plate over night or until the residue is white. While hot, reduce with stannous chloride solution, adding a drop at a time until the solution is colorless; stir well and add 3 drops in excess. Wash the solution into a 500 cc. beaker containing 200 cc. cold water and add all at once, 50 cc. mercuric chloride solution. Stir well

and titrate with a standard solution of potassium dichromate, adding enough to nearly oxidize all the iron, then a drop at a time, using as an external indicator a weak solution of potassium ferricyanide, dropped on a white tile. When no blue color is produced by the addition of a drop of the titrated solution to the indicator, the burette reading in cubic centimeters gives the percentage of iron in the ore.

SOLUTIONS.

Mercuric Chloride Solution.—Dissolve 50 grams of the salt in one liter of water.

Stannous Chloride Solution.—Dissolve 50 grams of stannous chloride in one liter of water.

Potassium Ferricyanide Solution.—About .040 grams are dissolved in 50 cc. water. Prepare this solution each day.

Potassium Dichromate Solution.—8.9 grams of the salt to a liter of water. Standardize with iron wire or a standard ore and dilute so that 1 cc. represents one percent of iron when one gram of ore is taken.

DETERMINATION OF PHOSPHORUS.

Weigh two grams of the dried ore (3 grams if the percent of phosphorus is low) into a 200 cc. beaker. Add 60 cc. hydrochloric acid; dissolve, and evaporate to dryness on the hot plate over night. Bake well until all acid fumes disappear; moisten with hot water; add 5 cc. nitric acid, cover with a watch-glass and heat for an hour on the hot plate. Dilute with water and filter through a 11 cm., S.&S., filter paper, into a 500 cc. Erlenmeyer flask, washing well with hot water. Heat the solution to 85°C.; add 5 grams of ammonium nitrate and shake. Then add 50 cc. molybdate solution; cover the flask with a cloth and shake for five minutes. Allow to settle and filter through a 9 cm. Munktell's filter paper. Wash the yellow precipitate ten times with 1½% nitric acid or until no iron is found in the washings when tested with potassium sulphocyanide. Wash finally with water. Place the funnel containing the precipitate into the flask in which it was precipitated; add 10 cc. ammonium hydroxide and wash with hot water. Pierce the paper with a platinum wire and wash with more ammonium hydroxide and hot water until all the yellow precipitate is dissolved. Add 10 grams of mossy zinc and 85 cc. of sulphuric acid solution. Boil for 15 minutes until the solution is olive green in color. Filter through purified cotton; wash with

cold water and titrate at once with standardized potassium permanganate.

SOLUTIONS.

Molybdate Solution.—100 grams of molybdic acid are dissolved in a mixture of 300 cc. water and 120 cc. ammonium hydroxide (sp. gr. .90). Filter and pour slowly into a mixture of 500 cc. nitric acid (sp. gr. 1.42) and 700 cc. of water. Let stand over night and filter.

Sulphuric Acid Solution.—One part sulphuric acid to three parts water.

DETERMINATION OF MANGANESE.

Dissolve from 3 to 5 grams of ore in hydrochloric acid and evaporate to dryness. Redissolve in hydrochloric acid and water, and filter. Ignite the insoluble residue. Fuse the residue with sodium carbonate; dissolve the fusion in hydrochloric acid and water, and filter into the first filtrate. To the combined filtrates add potassium chlorate and expel the excess of chlorine. Precipitate the iron as basic acetate by adding ammonia until a faint precipitate appears and then 25 cc. ammonium acetate solution. Boil for a minute and filter. Wash the precipitate with hot water and dissolve in dilute hydrochloric acid. Make a second basic acetate separation. Boil the combined filtrates down to a smaller volume and precipitate the manganese as dioxide with bromine solution. Filter; dissolve in hydrochloric acid; neutralize with ammonium hydroxide and reprecipitate the manganese as manganese ammonium phosphate with ammonium phosphate solution and strong ammonia. Ignite and weigh as manganese pyro-phosphate ($\text{Mn}_2\text{P}_2\text{O}_7$).

SOLUTIONS.

Ammonium Acetate Solution.—50 grams of the salt to a liter of water.

Ammonium Phosphate Solution.—225 grams of the salt to a liter of water.

DETERMINATION OF SILICA.

Dissolve 1 gram of the ore in 20 cc. hydrochloric acid. Dilute; filter; wash and fuse the residue with ten times its weight of equal parts of sodium and potassium carbonates. Dissolve the fusion in hydrochloric acid; evaporate to dryness and bake. Redissolve in hydrochloric acid; dilute and filter. Wash the residue with hot water; with dilute hydrochloric acid and finally with hot water. Ignite and weigh as SiO_2 .

XX. METHODS USED AT THE LABORATORY OF THE BARABOO DEVELOPMENT CO., BARABOO, WIS.

By THURMER HOGGARD.

DETERMINATION OF IRON.

The method is the same as described by C. J. Mott, with the following exceptions: Dilute (1:1) hydrochloric acid is used in dissolving the ore. On removing from the plate after the ore is dissolved, (if the solution is already discolored by an excess of the stannous chloride previously added), oxidize with a few drops of permanganate and then reduce.

REMARKS.

The above method gives excellent results when applied to ores practically soluble in hydrochloric acid, if the use of the acid and stannous chloride is carefully regulated. The mercuric chloride when added quickly should produce a fine, white, silky precipitate. Potassium permanganate will act on mercuric chloride if too much hydrochloric acid be present. The solution must be cold and dilute. An excess of stannous chloride precipitates metallic mercury and obscures the titration. Previous ignition of the ore is necessary if any appreciable organic matter is present.

MODIFICATIONS.

Pyrites, magnetites and certain silicates are not completely dissolved by hydrochloric acid without previous ignition. In the case of magnetites, complete solution can often be affected by the addition of 2 or 3 cc. of hydrofluoric acid to the ore in a platinum dish after partial solution in hydrochloric acid. The solution is then transferred to a beaker, reduced and titrated as above.

Where fusion of the ore is necessary, platinum is generally obtained in solution, due to the presence of manganese and possibly to some caustic or nitrate in the carbonates, which attack the crucible, and later being acted on by the tin, produces a deep red color of platinum chloride which tends to vitiate results. In this case transfer the hydrochloric solution of the ore to a 16 oz. Erlenmeyer flask and reduce with zinc as in the Emmerton method for phosphorus; cool; pour into a casserole containing 20 cc. of manganous sulphate; dilute and titrate with potassium permanganate. As both titanium and arsenic are reduced by zinc, the tin reduction will be found advan-

tageous where the ore can be obtained on solution without the interference of platinum.

SOLUTIONS.

Potassium Permanganate Solution.—28.6 grams of the pure crystalized salt are dissolved in a convenient volume of water and diluted to 10 liters. The solution is allowed to stand a few days in the dark; then siphoned off and standardized with 99.8% pure iron wire. Dilute until 1 cc. equals .005 gram of iron.

Stannous Chloride Solution.—250 grams of the salt dissolved in 300 cc. of strong hydrochloric acid and diluted to a liter.

Manganous Sulphate Solution.—160 grams of the salt dissolved in water and diluted to 1,750 cc. Then add 330 cc. of syrupy phosphoric acid (sp. gr. 1.70) and 320 cc. of concentrated sulphuric acid.

DETERMINATION OF PHOSPHORUS.

Weigh 2 grams of the ore into a 250 cc. beaker; add 30 to 40 cc. of strong hydrochloric acid and a few cc. nitric acid; cover, and boil to dryness on the hot plate. Take up with 10 to 15 cc. of strong hydrochloric acid; dilute, and filter into a 16 oz. Erlenmeyer flask. Wash; ignite and fuse the residue with about 6 times its weight of mixed carbonates (3 parts sodium to 1 of potassium). Boil out the fusion with water; acidify strongly with hydrochloric acid and evaporate to dryness (twice if the silica is to be determined from this weighing.) Take up with 10 cc. of strong hydrochloric acid; dilute; filter and add to the first filtrate. Neutralize the combined filtrates with ammonia adding 10 cc. in excess; redissolve with nitric acid to a light straw color. The volume should be kept within 150 cc. and contain 2 to 3 cc. of nitric acid in excess. Heat to 85°C. and add 50 cc. of ammonium molybdate solution; cork flask and shake vigorously for 3 to 5 minutes. Let the precipitate settle completely; filter through a 11 cm. No. 590 S.&S. paper, and wash thoroughly, first with 2% nitric acid and finally with 2% potassium nitrate. Transfer the filter and precipitate to a 250 cc. beaker; dissolve with standard sodium hydrate delivered from a burette, breaking up the filter with a stirring rod, and dilute with water previously freed of carbon dioxide by boiling. Add a few drops of phenolphthalein solution and titrate the excess of alkali with standard nitric

acid to the disappearance of the pink color. Each cc. of sodium hydrate required to dissolve the precipitate represents .01% phosphorus.

REMARKS.

In the presence of too much acid, especially hydrochloric, the precipitation is incomplete. If not enough acid is present basic iron salts are likely to form giving an orange color to the precipitate which cannot be washed out. Water distilled from carbonated waters often contains carbon which must be eliminated by boiling before it is used in the titration. Pure water has a tendency to dissolve the precipitate and cause it to run through the filter. Titanium delays the precipitation and interferes with the reaction by separating out when the solution is heated and carrying with it some P_2O_5 . Arsenic also forms an arsenio-molybdate precipitate and thus causing high results, and the precipitation is greater as the temperature is increased. Only traces of arsenic precipitate if the solution is not heated above 25° .

MODIFICATION FOR TITANIUM.

For ores carrying titanium the sample is fused with 8 to 10 parts of the mixed carbonates and the mass boiled out with water and filtered from the insoluble portion. The phosphorus passes into solution as a phosphate while the titanium remains as a titanate with the insoluble residue. The filtrate is acidified strongly with hydrochloric acid and evaporated to dryness; then moistened with HCl; diluted and filtered from the silica. To the filtrate add a few drops of ferric chloride; dilute; heat, and precipitate with ammonia. Filter and dissolve the oxide carrying the phosphorus with hot dilute nitric acid into a 16 oz. Erlenmeyer flask; dilute to 100 cc. and proceed in the usual manner.

MODIFICATION FOR ARSENIC.

The method described by J. M. Camp in Phillips' "Methods of Iron Analysis" is used.

SOLUTIONS.

Molybdate Solution.—500 grams of pure molybdic anhydride (Merck's) are mixed with 1,000 to 1,500 cc. water and 600 cc. of strong ammonia added. When dissolved allow to settle; filter through a folded filter and dilute to 2,600 cc. Pour this with constant agitation into a 10 liter bottle containing a mixture of 2,000 cc. nitric acid and 3,000 cc. water, and agitate thoroughly. Let the solution stand until the precipitate

has settled and draw off about a liter of the clear portion at intervals as needed, filtering if necessary.

Standard Sodium Hydrate.—80 grams of the caustic are dissolved in about a liter of pure water, and a saturated solution of barium hydrate added as long as a precipitate forms. Filter at once from the barium carbonate and dilute to 10 liters.

Standard Nitric Acid.—10 cc. of strong nitric acid to a liter of water. Make equal to the standard sodium hydrate.

Yellow Precipitate (for standardizing).—5 to 10 grams of the precipitate are prepared at intervals by treating a dilute solution of sodium phosphate with an excess of the molybdate solution. The precipitate is then washed thoroughly with 1% nitric acid and dried at 130°C. in the air bath. Transfer at once to a small tube and cork tightly. The precipitate is supposed to contain 1.63% phosphorus.

STANDARDIZATION OF SOLUTIONS.

Run into a 250 cc. beaker 20 cc. of the sodium hydrate solution and dilute to 100 cc.; add a few drops of phenolphthalein indicator and titrate with nitric acid solution. Then to .1227 gram of the yellow precipitate add 20 cc. of the sodium hydrate and dissolve completely; dilute to 100 cc. and titrate the excess of alkali as before. The difference in the amount used in the two cases is the number of cc. of the acid that is equivalent to .002 gram of phosphorus. Dilute the acid until 10 cc. is equivalent to .002 gram of phosphorus. Make the sodium hydrate solution equal in strength to the nitric acid solution.

For a 2 gram sample of the ore 1 cc. of the alkali is equivalent to .01% phosphorus. A steel of known phosphorus content is used to check this solution.

DETERMINATION OF MANGANESE.

Volhard's method, slightly modified.

Digest 1.473 grams of ore in a 600 cc. beaker with 20 cc. of strong hydrochloric acid and a few crystals of potassium chlorate. (Previously ignite if organic matter be present). Boil until the excess of acid is expelled; remove from the plate; cool; dilute slightly and nearly neutralize with sodium carbonate. Add zinc oxide, suspended in water, in slight excess to completely precipitate the iron; dilute to about 400 cc.; heat to nearly boiling and titrate with potassium permanganate, (as used in the iron determination) in the presence of the heavy precipitate, to a faint pink color. The iron precipitate aids in

the titration by collecting the manganese dioxide precipitated and clarifying the solution.

Since 1 cc. of the permanganate solution is equivalent to .005 gram of iron, the factor for 1 cc. in terms of manganese is .001473 gram; and for 1.473 grams of the sample taken, 1 cc. represents .001 or .1% manganese.

DETERMINATION OF SILICA.

The insoluble residue from the first filtration in the phosphorus determination is used; or proceed with 1 to 2 grams of the ore as in the determination of phosphorus. Moisten the residue with hydrochloric acid and evaporate to dryness twice. Moisten with strong hydrochloric acid; dilute to about 200 cc.; filter and wash well with hot water. A thorough washing is necessary as alkaline salts are tenaciously held by the silica. Transfer the silica to a platinum (or porcelain) crucible; char the paper carefully in the front part of the muffle, as heating too suddenly is liable to cause a loss by blowing out of the silica. Finally ignite in the hottest part of the muffle, and when the contents are thoroughly incinerated, cool in a desiccator and weigh as silica.

MODIFICATION.

In the presence of barium or much alumina the silica weighed in the crucible is volatilized as silicon fluoride by adding a few drops of sulphuric acid and 2 to 3 cc. of hydrofluoric acid. Evaporate to dryness; ignite and weigh. The loss in weight equals the silica.

DETERMINATION OF SULPHUR.

(*By wet oxidation*).—To 1 to 3 grams of the pulverized ore weighed into a 4-inch casserole, add 25 to 50 cc. nitric acid and a few crystals of potassium chlorate and boil until the excess of nitric acid is expelled. Then add 25 cc. of strong hydrochloric acid and boil to dryness. Take up with HCl (a slight excess); dilute; filter into a 250 cc. beaker and wash thoroughly with hot water. Bring the volume of the filtrate, containing about 5 cc. of hydrochloric acid in excess, to 100 cc.; heat and add 25 cc. of hot barium chloride (10% solution) slowly to the solution while boiling, stirring constantly. Boil down to about 75 cc. and allow to settle in a warm place. Filter and wash well with hot water, moistening the paper once or twice with dilute HCl. Transfer the filter and precipitate to a porcelain crucible and "smoke off" the paper carefully at a low temperature in

the front part of the muffle. Ignite gradually to bright redness until the paper is consumed. Brush from the crucible and weigh as BaSO_4 .

(*By Fusion.*)—Fuse in the muffle .5 to 1 gram of the ore with about 8 parts of the mixed carbonates and .5 gram of sodium nitrate in a covered platinum crucible, gently at first, until all action has ceased. Cover the mass with a portion of the fusion mixture to prevent loss of sulphur from the sulphides if heated too suddenly. Pour the fusion into a platinum dish floating on water and when cool transfer both the mass and crucible to a 4-inch casserole and dissolve out with hot water. When the mass is thoroughly disintegrated, filter and wash well with hot water; acidify the filtrate with hydrochloric acid and evaporate to dryness. Moisten with hydrochloric acid, dilute and filter from silica. Bring the filtrate, which should not exceed 100 cc., to a boil and proceed as in the "wet oxidation method."

DETERMINATION OF ALUMINA.

Digest 2 grams of the ore in a 250 cc. beaker with 30 cc. of strong hydrochloric acid and a few drops of potassium chlorate. Boil to dryness; take up with 10 to 15 cc. of strong hydrochloric acid; dilute; filter and treat the residue as in the fusion method for silica. Combine the filtrates from the silica and residue and make up to 400 cc. Pour off 200 cc. into a 600 cc. beaker, reserving the other portion for the determination of lime and magnesia.

Dilute the alumina portion to 400 cc.; add 3 grams of ammonium phosphate in solution and then ammonia until a slight permanent precipitate is obtained. Add 1.5 cc. strong hydrochloric acid and 10 grams of sodium hypo-sulphite bring to a boil and add 8 cc. of strong acetic acid and 15 cc. of a 20% solution of ammonium acetate. Boil for about 20 minutes, or until the precipitate coagulates. Remove beaker and when the precipitate has settled, decant through a filter; add about 100 cc. of hot water to the precipitate, filter and wash 8 to 10 times with hot water, and dry the filter in a porcelain crucible. Char the paper in the front part of the muffle and finally heat to a bright redness until the paper is consumed. Cool in a desiccator and weigh as AlPO_4 .

DETERMINATION OF LIME.

To the lime and magnesia portion from the alumina determination, in a 1,000 cc. beaker, add about 600 cc. water and a

few cc. of bromine water; heat and precipitate with a slight excess of ammonia, boil for a few minutes, remove and make up to 1,000 cc. with water free of carbon dioxide. Pour off 500 cc. (representing .5 gram of ore) through a folded filter; evaporate to about 150 cc. and while still hot add 25 cc. of a hot saturated solution of ammonium oxalate. Continue the boiling for 10 minutes; let the precipitate settle; filter into a 16 oz. Erlenmeyer flask and wash well with hot water. Remove the filtrate after the first two washings and reserve it for the magnesia determination.

After thorough washing replace the filter and precipitate in the beaker in which the precipitation was made; add about 400 cc. of hot water and 15 to 20 cc. of (1:1) sulphuric acid; break up the filter and titrate with potassium permanganate.

The strength of the permanganate in terms of CaO equals $\frac{1}{2}$ the iron value. Since the iron value in this case is equivalent to .005 gram or .5% the number of cc. of KMnO_4 times $\frac{1}{2}$ of .5 divided by .5 the weight of ore taken equals the percentage of CaO; or 1 cc. KMnO_4 equals .5% CaO.

DETERMINATION OF MAGNESIA.

Cool the precipitate, from the calcium oxalate precipitation, which should not exceed 350 cc. and add 15 to 20 cc. of sodium phosphate solution; with constant agitation add about 1-10 its volume of ammonium hydrate; stopper and shake well to facilitate the precipitation; let stand in a cool place to settle; filter and wash well with (1:4) ammonium hydrate solution, a thorough washing being necessary to remove all the alkaline salts. Place the filter in a weighed porcelain or platinum crucible; dry; char the paper carefully at a low heat in the front part of the muffle and gradually bring to bright redness, continuing the ignition until the precipitate is white. Cool in a desiccator and weigh as $\text{Mg}_2\text{P}_2\text{O}_7$.

Note.—If the crucible is heated too suddenly before the paper is charred there is danger of loss, and of the mass sintering and enclosing particles of the filter which are difficult to incinerate.

DETERMINATION OF TITANIUM.

To 1 or 2 grams of the ore in a platinum dish add about 50 cc. of strong hydrochloric acid and boil gently until the ore appears to be dissolved. Add 15 to 20 cc. (1:4) sulphuric acid and 2 to 3 cc. of hydrofluoric acid and heat till fumes of sulphur

trioxide (SO_3) appear. Avoid heating too long as there is danger of TiO_2 separating in an insoluble form. Cool; and add about 50 cc. water and heat until the iron salts are dissolved. The silica should now be practically expelled and the TiO_2 all in solution.

Transfer the solution to a 600 cc. beaker and dilute to about 300 cc.; add ammonium hydrate until the precipitate formed dissolves on stirring. Warm the solution and add sodium sulphite, a little at a time, until the deep color produced by each addition disappears as the iron is reduced. Do not heat the solution to boiling as TiO_2 will separate and render complete reduction difficult to distinguish. Clarify the solution, if any turbidity appears while adding the sulphite, with a few drops of hydrochloric acid. About 50 cc. of the sulphite solution should be sufficient to complete the reduction. The solution should be colorless and smell strongly of sulphur dioxide. Now add about 50 cc. of acetic acid and 20 grams of sodium acetate, and boil vigorously for 5 minutes. Let the precipitate settle; filter and wash with hot water. Dry and ignite the filter in a platinum crucible.

The TiO_2 precipitate is impure, containing all the phosphorus and possibly some iron and silicious matter.

To the impure precipitate add 8 to 10 times its weight of dry sodium carbonate and fuse in the muffle until all action has ceased. Cool and boil in water until the mass is thoroughly disintegrated and the insoluble portion is flocculent. Filter and wash with hot water; wash the precipitate back into the beaker; let settle, and decant the clear portion through the filter again. Dissolve any adhering residue from the filter, into the beaker containing the filtrate, with hydrochloric acid; add a little hydrochloric acid to the solution in the beaker and about 10 cc. of (1:4) sulphuric acid and boil until the hydrochloric acid is expelled. All should go into solution. Avoid over-heating. Cool; add 25 cc. water; boil and filter from any silica that may be present. Dilute the filtrate to about 250 cc.; reprecipitate with ammonium hydrate as before; redissolve with hydrochloric acid and add 10 cc. of sodium sulphite solution. Dissolve any precipitate that forms, with a few drops of hydrochloric acid. Heat the solution gradually until all color disappears and proceed as in the original treatment of the solution. Dry and ignite intensely the second precipitate, which should be pure. Weigh as TiO_2 .

SOLUTION.

Sodium Sulphite.—Add sulphuric acid to 1 part of the salt and 5 of water until the solution is distinctly acid.

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**XXI. METHODS USED AT THE LABORATORY OF THE ILLINOIS
IRON MINING CO., ILLINOIS MINE, BARABOO
VALLEY, NORTH FREEDOM, WIS.**

BY VICTOR RAKOWSKY.

DETERMINATION OF IRON.

The method is the same described by C. J. Mott, with the following exceptions: 40 cc. of titrating solution and 20 cc. mercuric chloride are used. The solutions are the same and of the same strength except the phosphoric acid or titrating solution which is made up as follows: 800 grams of manganous sulphate dissolved in 4 liters of distilled water. To this add 4 liters of phosphoric acid (sp. gr. 1.70), 2,400 cc. distilled water and 1,600 cc. concentrated sulphuric acid.

VARIATIONS.

Occasionally samples taken from the breasts of drifts or sub-levels will give an insoluble residue in concentrated hydrochloric acid, in which case fusion with bisulphate of potassium is necessary. This residue is chromite.

DETERMINATION OF PHOSPHORUS.

Gravimetric method.

Weigh 4.89 grams of the 100 mesh ore pulp. Put into a 300 cc. Erlenmeyer flask covered closely with a small funnel; add 70 cc. concentrated hydrochloric acid and boil vigorously until dissolved. Filter while hot into a 500 cc. flask and place on a steam plate. Fuse the residue with sodium carbonate; digest in a flat 500 cc. beaker with a few drops of dilute hydrochloric acid. Filter into the main solution; cool rapidly by immersing in cold water; add ammonium hydrate in slight excess; redissolve the precipitate with strong nitric acid; cool to 40°C. and add 50 cc. of molybdate solution. Shake the flask vigorously and the yellow phospho-molybdate precipitate separates quickly. Filter on tared filters; wash thoroughly with 1% nitric acid and with water; dry at 110°C.; cool in a desiccator and weigh. The weight divided by 3 gives the percent of phosphorus.

Tared Filters.—Two 9 cm. No. 0 Munktell's filters are weighed in counterpoise and small amounts cut from the end of the heavier. They are then dried at 110°C . and reweighed. The whole filter is placed inside the other and the precipitate collected on this.

SOLUTIONS.

Molybdate Solution.—Dissolve 100 grams of molybdic anhydride in a solution of 400 cc. cold water and 80 cc. ammonium hydrate. Pour this into a solution of 400 cc. nitric acid and 600 cc. water, shaking constantly. Add 50 grams of microcosmic salt dissolved in a little water.

Note.—It is absolutely necessary to fuse the residue from the hydrochloric acid solution or the results will be decidedly too low.

DETERMINATION OF SILICA.

Dissolve 1 gram of the ore in 15 cc. hydrochloric acid in a wide 500 cc. beaker; evaporate to dryness, adding a few drops of strong nitric acid before dry. Dissolve in dilute hydrochloric acid and filter. Fuse the residue with sodium carbonate; digest with dilute hydrochloric acid; evaporate to dryness and redissolve in dilute HCl. Filter; ignite the residue, and weigh. Eliminate the silica with hydrofluoric acid and reweigh. The difference in weights represents the silica.

Fusion is made by a Hoskin's burner. To complete fluidity the hot crucible is thrown into water contained in a small casserole.

XXII. METHODS USED AT THE LABORATORY OF THE LAKE SUPERIOR POWER COMPANY, HELEN MINE, ONTARIO.

By L. L. BOLTON, M. A.

PREPARATION OF SAMPLE.

Grind the ore sample to pass through a 100-mesh sieve and dry at 110°C . On removal from the drying cupboard, cool the sample in a desiccator.

DETERMINATION OF IRON.

Weigh 1 gram of the dried sample into a tall narrow 150 cc. beaker. Add 20 cc. of strong hydrochloric acid and 3 cc. of stannous chloride solution. Cover the beaker with a watch-glass and place on a hot plate where the solution is

allowed to boil gently until the ore is dissolved. Remove and wash the watch-glass and sides of the beaker carefully with hot water. To the hot solution add stannous chloride solution from a burette until the reduction of the ferric chloride is complete, observing the customary precautions; pour into another beaker containing 400 to 500 cc. of cold water and rinse the smaller beaker carefully with a jet from a wash-bottle; add 25 to 30 cc. of mercuric chloride solution to take up the excess of stannous chloride; allow to stand for one or two minutes and titrate with a standard solution of potassium bichromate.

Test the progress of the oxidation of the ferrous chloride from time to time by transferring a drop of the solution on a glass rod to one of several drops of potassium ferricyanide previously placed on a white porcelain plate, a bluish coloration is produced by the ferrous iron still unoxidized. As the blue color becomes less intense add the bichromate in smaller quantities between successive tests, and finally a drop at a time, stirring well after each addition. Add two or three drops of the solution at a time to one drop of the ferricyanide solution and when no blue coloration appears within 30 to 40 seconds the titration may be considered complete. Read the burette and calculate the percentage of iron.

SOLUTIONS.

Stannous Chloride Solution.—Make a saturated solution by dissolving mossy tin in strong hydrochloric acid. Filter and add an equal volume of strong hydrochloric acid. About 7 to 8 cc. of this solution will reduce the solution of one gram of ore running 60% iron.

Mercuric Chloride Solution.—50 grams of the salt to a liter of distilled water.

Potassium Ferricyanide Solution.—About .04 gram to 24 cc. water. Make this solution up daily.

Potassium Bichromate Solution.—Prepare a strong solution of 50 grams of the salt to a liter. Dilute portions from time to time as needed to make a solution one cc. of which is approximately equivalent to one percent of iron when a one gram sample is taken. Standardize with fine iron wire.

DETERMINATION OF PHOSPHORUS.

Treat 2 grams of the dried ore in a 250 cc. beaker with 30 cc. of strong hydrochloric acid. When the ore is dissolved evaporate to dryness. Remove the beaker from the hot plate and cool; take up the residue with 20 cc. of strong hydrochloric

acid; dilute and filter the solution from the insoluble residue into a 600 cc. Erlenmeyer flask. Evaporate this filtrate to as small volume as possible, add about 35 cc. of nitric acid and again evaporate to a small volume. Remove from the hot plate and when cool, add ammonia in slight excess, then nitric acid, obtaining a temperature of from 75° to 85° . Add 50 cc. of molybdate solution and impart a whirling motion to the flask for five minutes, then let stand at about 50° until the supernatant liquid is clear. Filter on a 9 cm. filter paper, washing the flask thoroughly with acid ammonium sulphate solution. Rinse down the sides of the flask in which the precipitation was made with dilute ammonia; place the funnel containing the yellow precipitate in the neck of the flask and dissolve with dilute ammonia; wash twice with boiling water. Make up the solution to about 125 cc.; add 15 grams of 20-mesh powdered zinc, and 25 cc. of strong sulphuric acid. Let stand in the cold five minutes, then twenty minutes on the hot plate, gradually increasing the temperature to finally boiling for five minutes. Filter into a flask through a plug of absorbent cotton held in a glass funnel; and wash flask and funnel thoroughly with hot water. Titrate hot with a standard solution of potassium permanganate until a pink color remains after the solution stands one minute. From the burette reading subtract the correction necessary for 15 grams of zinc, as previously determined from a blank test, and calculate the percentage of phosphorus.

SOLUTIONS.

Molybdate Solution.—In a liter flask make an emulsion with 120 grams of c.p. molybdic acid and 300 cc. of distilled water; add 175 cc. of ammonia and shake until the acid is dissolved. Add 75 cc. nitric acid and shake until the precipitate which at first forms redissolves. Add this solution to a mixture of 500 cc. nitric acid and 1,200 cc. water in a winchester, making sure that both solutions are cold before mixing. If necessary filter before using. Keep in the dark.

Acid Ammonium Sulphate Solution.—Two liters of water, 50 cc. strong sulphuric acid and 30 cc. ammonia.

Ammonia Solution.—One liter of ammonia to two liters of water.

Potassium Permanganate Solution.—Prepare a solution one cc. of which is equivalent to .0066 grams of iron, standardizing with fine iron wire, and determine the phosphorus value

by multiplying the iron value by the factor .01581. When two grams of ore are used one cc. of this solution is equivalent to about .005% phosphorus.

DETERMINATION OF SULPHUR.

The method used is a modification of the Aqua Regia method and is practically the same as that used in the laboratory of the Canada Iron Furnace Co., at Midland, Ontario. The method is similar to that of Mr. A. B. Harrison as described in Phillip's "Methods of Iron Analysis".

Weigh three grams of the sample into a 250 cc. Jena glass beaker. Prepare a mixture of 40 cc. strong nitric acid and 20 cc. strong hydrochloric acid and add to the ore in the beaker; place on a hot plate and heat to boiling. Watch carefully while boiling to prevent bumping, which tendency may be lessened by adding from time to time small quantities of hydrochloric acid until 20 to 25 cc. have been added. Evaporate the solution to dryness; remove from the hot plate and cool. When cool add 15 cc. hydrochloric acid and again evaporate to dryness. Cool; add about 30 cc. hydrochloric acid; cover with watch-glass and heat on the hot plate until the residue is digested. Dilute with hot water and filter into a low 150 cc. beaker, using a filter of close texture. (If evaporation has been carried too far some ferric oxide may be formed and small undissolved particles may pass through the filter; care should be taken not to convert ferric chloride to ferric oxide lest the ferric sulphate be decomposed at the same time.) Wash the filter twice with hot dilute hydrochloric acid (1:1), and thoroughly with boiling water, keeping the volume of the filtrate as small as possible. Boil for a few minutes and add 10 cc. of 10% solution of barium chloride. Continue the evaporation until a crust of ferric chloride crystals forms in the bottom of the beaker. Add about 1 cc. of hydrochloric acid and 60 cc. water and let stand near edge of hot plate until clear. Filter and wash, first with hot dilute hydrochloric acid and thoroughly with hot water. Ignite and weigh as BaSO_4 .

If the presence of silica in the precipitate be suspected add 1 cc. of hydrofluoric acid, evaporate carefully and weigh again.

CAUTION.

At least two hours should be taken to concentrate the filtrate from the insoluble residue to the point where it is diluted

with hot water, else the precipitation of BaSO_4 may be incomplete.

DETERMINATION OF MOISTURE.

Crush the sample to pass through a $\frac{3}{8}$ "-mesh sieve. After thoroughly mixing take 100 grams and dry on a watch-glass at 110°C . from one to one and a half hours. Weigh again, taking the loss in weight as moisture.

XXIII. METHODS USED AT THE LABORATORY OF THE MANISTIQUE IRON COMPANY, MANISTIQUE, MICHIGAN.

By J. P. GRIFFITH.

DETERMINATION OF IRON.

Weigh 1 gram of the finely ground ore, dried at 100°C ., into a 200 cc. lipless beaker. Dissolve in 20 cc. hydrochloric acid, with the addition of 10 cc. stannous chloride solution to aid solution. When dissolved complete the reduction by the addition of stannous chloride, drop by drop, until the solution is colorless. Transfer to a 500 cc. beaker, diluting with water to about 400 cc.; add 10 cc. saturated solution of mercuric chloride, and stir thoroughly. Titrate with potassium bichromate solution, until a drop of the solution added to a drop of potassium ferricyanide solution on a waxed porcelain plate shows no green color. The number of cc. of potassium bichromate solution used, equals the percentage of iron in the ore.

SOLUTIONS.

Potassium Bichromate Solution.—8.8 grams of the salt dissolved in a liter of water. Standardize with an iron ore of known percent, diluting so that one cc. equals one percent of iron.

DETERMINATION OF PHOSPHORUS.

Weigh out one gram of finely ground ore, dissolve in 10 cc. concentrated hydrochloric acid, with the addition of a few drops of strong nitric acid. Evaporate to 4 or 5 cc.; dilute with water and filter into a 16 oz. flask. Make alkaline with ammonia and redissolve the precipitated iron with nitric acid, obtaining an amber colored solution. Heat to 85°C .; add 60 cc. of molybdate solution, and shake with a whirling motion for five minutes. Filter with the aid of a filter pump and proceed

according to the Handy method, dissolving in sodium hydrate and titrating back with nitric acid.

SOLUTIONS.

Molybdate Solution.—Dissolve 100 grams of molybdic acid in a mixture of 300 cc. ammonia and 100 cc. water. When cold add at once to a cold solution of 500 cc. nitric acid and 100 cc. ammonia.

DETERMINATION OF SILICA.

Except when absolutely accurate results are desired, the method given in "Blair's Chemical Analysis of Iron", page 231, second edition, is used, determining the silica as insoluble silicious matter.

DETERMINATION OF MANGANESE.

Volhard's method as given by Prof. Crobaugh, in his "Methods of Chemical Analysis", page 46, second edition, is used.

XXIV. METHODS USED AT THE LABORATORY OF THE REPUBLIC IRON AND STEEL CO., NEGAUNEE, MICH.

By A. F. BENSON.

DETERMINATION OF IRON.

Take a factor weight sample of the ore, about .5 gram. Dissolve in about 10 cc. of strong hydrochloric acid in a 60 cc. covered beaker, on a steam bath. On a hot plate it is likely to boil too vigorously thereby volatilizing some of the ferric chloride. Digest until the residue is of a uniform grayish color; remove and wash off the cover into the beaker with a jet of water. The solution will be a reddish brown color due to the presence of ferric chloride. Reduce to the ferrous condition by a solution of stannous chloride which is run in carefully in a small stream, with constant stirring, until the solution is decolorized. Add two or three drops in excess to insure complete reduction. Dr. G. A. Koenig adds enough stannous chloride to produce a white silky appearance when the mercuric chloride is added. Now add 15 cc. of phosphoric acid stock solution and 10 cc. of saturated mercuric chloride solution. If too much stannous chloride has been used, a dark grey precipitate is thrown down, in which state the solution should not be

titrated. Transfer to a 600 cc. beaker and wash the small beaker well. Dilute to about 300 cc. and titrate at once with standard potassium permanganate solution. The burette reading gives the percentage of iron.

DETERMINATION OF PHOSPHORUS.

Take a factor weight sample of the ore, about 2 grams. Dissolve in 20 to 40 cc. hydrochloric acid in a 100 cc. beaker, with a watch-glass cover. Boil until the insoluble residue presents no dark spots, but is of a uniform grayish color. If difficult to dissolve, add a little nitric acid. This operation generally takes from a half to one hour. Remove from the hot plate, wash off the cover into the beaker and wash down the inside of the beaker, thereby diluting the acid to prevent it attacking the paper. Filter into a 500 cc. Erlenmeyer flask. Wash the residue thoroughly with water. To the filtrate add ammonia (sp. gr. .90) until a permanent dense precipitate forms.

Care should be taken not to have too great an excess of ammonia, as too much ammonium chloride and nitrate would interfere with the complete precipitation of the phosphorus. Redissolve the precipitate with just enough nitric acid (sp. gr. 1.42) to obtain a deep reddish brown solution, then drop by drop until the solution is of an amber color. Heat to 75°C. and add 20 cc. of molybdate solution; shake and let stand for an hour. Filter out the yellow ammonium phospho-molybdate on a 9 cm. filter paper, carefully washing the precipitate from the flask on the filter. Wash six times with 1% nitric acid and six times with 1% potassium nitrate solution. Introduce the paper and precipitate into the flask, after thoroughly rinsing the same, and add about 80 cc. water. Shake to break up the paper. Add an excess of a standard sodium hydrate solution to dissolve the precipitate. Add a few drops of phenolphthalein indicator and titrate the excess of alkali with a standard nitric acid solution of equal strength, until the red color disappears. The difference between the number of cc. of alkali and acid used times .01 gives the percentage of phosphorus, when a factor weight sample is taken.

TO DETERMINE A FACTOR WEIGHT.

Weigh out a .5 gram sample of standard ore, the percent of iron in which is known, (to be say 60.70%). Suppose that the determination requires 65.20 cc. of the standard permanganate solution in the titration. Let x be the factor weight; then we have $x : 61.70 = .5 : 65.20$ whence $x = .4732$. Verify

by taking a sample of standard ore of this weight making a determination of iron. Use this factor weight for all iron samples until the strength of the solution necessitates a new factor or a new solution as made up. The factor for phosphorus is determined in a similar manner.

SOLUTIONS.

Molybdate Solution.—(A.) To a mixture of 227 grams of 85% molybdic acid. 600 cc. water, 350 cc. ammonia (sp. gr. .90) add 150 cc. nitric acid. (B.) 2,400 cc. water and 945 cc. nitric acid.

Mix, adding A. to B., at same temperatures.

1% Nitric Acid Solution.—13 cc. nitric acid to a liter of water.

1% Potassium Nitrate Solution.—10 grams of the salt to a liter of water.

Phenolphthalein Solution.—1 gram of the powder to 500 cc. 95% ethyl alcohol. Use 3 or 4 drops.

Standard Sodium Hydrate Solution.—To 100 grams of pure sodium hydrate add enough water to make a saturated solution. Pour into a tall cylinder and let any insoluble matter settle. Pipette or siphon off and dilute in the proportion, 30 cc. to 2 liters of water.

Standard Nitric Acid Solution.—20 cc. nitric acid (sp. gr. 1.42) are thoroughly mixed with 2 liters of water in a 2 liter glass stoppered bottle, and diluted, making 1 cc. equivalent to 1 cc. of the standard nitric acid solution.

Standard Potassium Permanganate Solution.—30 oz. potassium permanganate crystals to 32 liters of water.

Phosphoric Acid Stock Solution.—(A.) 160 grams of manganous sulphate crystals to 1,750 cc. water. (B.) 330 cc. strong sulphuric acid to 320 cc. phosphoric acid (sp. gr. 1.71). Mix A. and B.

REMARKS.

The method described for the determination of phosphorus is adapted to the general run of iron ore in this district. We cannot, however, recommend it for all ores, or for specific technical work outside of the iron laboratory.

Standard and washing solutions are kept in carboys over the laboratory from which they are siphoned to the work table.

For other determinations and for complete analysis we use schemes chiefly from Dr. Koenig, Fresenius and Blair.

XXV. METHODS USED AT THE LABORATORY OF THE CLEVELAND-CLIFFS IRON CO., ISHPEMING, MICH.

By F. J. BAKER.

DETERMINATION OF IRON.

Dissolve the factor weight of ore (about .5 gram) in 5 to 6 cc. solution B. Reduce completely with solution C. and add about 5 cc. solution D. Rinse into a No. 3 Griffin beaker; add 10 cc. solution E. and titrate with solution A. The burette reading gives the percent of iron.

SOLUTIONS.

A. *Potassium Permanganate*.—116 grams of potassium permanganate dissolved in 40 liters of water.

An iron ore that has been analyzed by several chemists is used to standardize this solution.

B. *Stannous Chloride and Hydrochloric Acid*.—8 oz. stannous chloride dissolved in 5 pints of hydrochloric acid (sp. gr. 1.15).

C. *Stannous Chloride and Hydrochloric Acid*.—7 oz. stannous chloride dissolved in 500 cc. hydrochloric acid and diluted with water to 5 pints.

D. *Mercuric Chloride*.—A saturated solution.

E. *Titration Solution*.—5.5 oz. manganese sulphate dissolved in water; add 250 cc. phosphoric acid, fill bottle (5 pt.) to within an inch of the top, with water and add 150 cc. sulphuric acid.

DETERMINATION OF PHOSPHORUS.

Dissolve $\frac{1}{2}$ the phosphorus factor weight of ore (about 2 grams) in hydrochloric acid in a No. 3 usual form beaker. Add a few drops of nitric acid and evaporate to about 7 cc. Dilute and filter into a 16 oz. Erlenmeyer flask, using Munktell's No. 3, 9 cm. filter paper. By careful washing the solution will be about 55 cc. Add ammonium hydrate until a slight precipitate of iron remains after violent shaking. Dissolve this precipitate with a few drops of nitric acid. Add molybdic acid solution (30 cc. is sufficient for .250% phosphorus) and heat to 60°C. Shake the flask five or six times at short intervals and let stand for 15 or 20 minutes. Filter through a 12½ cm. Munktell No. 3 filter; wash three times with a 1% sulphuric acid solution. Dissolve the precipitate with 20% ammonium hydrate solution and rinse down with about 5 cc. water. Re-

duce with No. 20 granulated zinc and sulphuric acid, and filter through the original precipitate filter, into a No. 4 beaker. Titrate with potassium permanganate solution, which is standardized by a standard ore determination. Twice the burette reading gives the percent of phosphorus.

DETERMINATION OF MANGANESE.

Dissolve 1 gram of ore (if not more than 5% manganese, $\frac{1}{2}$ gram, if more) in hydrochloric acid. Add a few drops of nitric acid and evaporate to dryness. Redissolve in hydrochloric acid and boil for 15 minutes. Evaporate to about 10 cc., rinse into a 14 oz. beaker and fill 2-3 full with boiling water. Neutralize with sodium carbonate to a deep red color and add zinc oxide in excess, precipitating all the iron. Titrate as quickly as possible with potassium permanganate solution, used for iron determination, to a pink color. The iron factor times .295 gives the manganese factor, which multiplied by the burette reading give the percent of manganese, when 1 gram of ore is used.

DETERMINATION OF SILICA.

The sodium carbonate fusion method is used.

DETERMINATION OF ALUMINUM.

A modification of Peters' method, as given in Blair's "Chemical Analysis of Iron", is used.

Precaution.—Have a very small amount of hydrochloric acid in the solution when ready to neutralize with ammonia.

DETERMINATIONS OF CALCIUM, MAGNESIA AND SULPHUR.

The methods, given in Blair's "Chemical Analysis of Iron", are used.

XXVI. METHODS USED AT THE LABORATORY OF THE REPUBLIC IRON COMPANY, REPUBLIC, MICHIGAN.

By W. A. SIEBENTHAL.

DETERMINATION OF IRON.

Weigh .5 gram of ore into a 100 cc. beaker; add about 5 cc. stannous chloride solution, 5 to 8 cc. water and 20 cc. hydrochloric acid. Boil gently until dissolved. Complete the reduc-

tion with stannous chloride solution; wash into an evaporating dish, adding about 300 cc. cold water. Add 20 to 25 cc. saturated solution of mercuric chloride; stir for about a minute and titrate with standard potassium bichromate solution, using a weak solution of potassium ferricyanide, on a porcelain plate, as an indicator.

SOLUTIONS.

Potassium Bichromate Solution.—66.29 grams of the salt dissolved in water and made up to about 15 liters, so that 1 cc. is equivalent to 1% iron when a half gram sample is taken. Sometimes the solution is made up to 15 liters and a factor weight determined. Standardize with iron wire or a standard ore.

Stannous Chloride Solution.—The same as given by F. A. Janson.

DETERMINATION OF PHOSPHORUS.

Weigh 3 grams of ore into a 250 cc. Griffin beaker; add 5 to 10 cc. water and 40 to 50 cc. hydrochloric acid, and boil until dissolved. Remove cover and evaporate to dryness or nearly so. Add about 10 cc. nitric acid, cover and boil until redissolved; remove cover and evaporate the excess of nitric acid. Dilute and filter into a 300 cc. Erlenmeyer flask; heat to about 75°C.; add ammonia in excess; neutralize with nitric acid; add 20 cc. molybdic acid solution and shake for about a minute, let stand for about 5 minutes at a temperature of about 60°C., then set aside on the laboratory table until the precipitate has settled and the supernatant liquid is clear. Siphon off the clear solution, and filter on a No. 1F, 9 cm. Munktell filter paper. Wash the flask twice with a fine stream of 2% ammonium nitrate solution, washing all the precipitate on the filter. Wash three times with the ammonium nitrate solution and two or three times with distilled water, to free the filter and precipitate of all acid. Place the filter containing the precipitate into the flask previously used, after thoroughly rinsing the same, add an excess of standard sodium hydrate solution and break up the filter paper with a stirring rod, rinsing down the sides of the flask and the rod. Titrate the excess of alkali with standard nitric acid solution, using a few drops of phenolphthalein solution as an indicator. The number of cc. of alkali required in dissolving the yellow precipitate times the factor for 1 cc. (about .003) gives the percent of phosphorus in the ore.

SOLUTIONS.

Molybdic Acid Solution.—The same as given by F. A. Janson.

Standard Sodium Hydrate Solution.—45 grams of pure sodium hydrate sticks dissolved in water and made up to about 15 liters, so that 30 cc. are equivalent to 20 cc. of a tenth normal oxalic acid solution. Standardize on a standard ore or with pure yellow ammonium phospho-molybdate powder, and determine the factor for 1 cc.

Standard Nitric Acid Solution.—68 cc. of nitric acid (sp. gr. 1.42) diluted to about 15 liters with distilled water, so that 1 cc. is equivalent to 1 cc. of the standard alkali solution.

A MORE RAPID METHOD FOR PHOSPHORUS.

Weigh 3 grams of ore into a 200 or 250 cc. beaker; add 12 to 15 cc. of nitro-hydrochloric acid, cover and boil vigorously for 5 minutes, or let stand cold for 10 to 15 minutes with whirling at frequent intervals so that the acid may reach all the particles of ore. Remove cover, dilute and filter. Wash filter twice with hot water. Heat to 75°C.; add ammonia in slight excess and neutralize with nitric acid. Add 20 cc. molybdic acid solution and shake vigorously for 30 to 60 seconds; let stand in hot water at 75°C. for a minute and filter at once, proceeding as in the regular method described above.

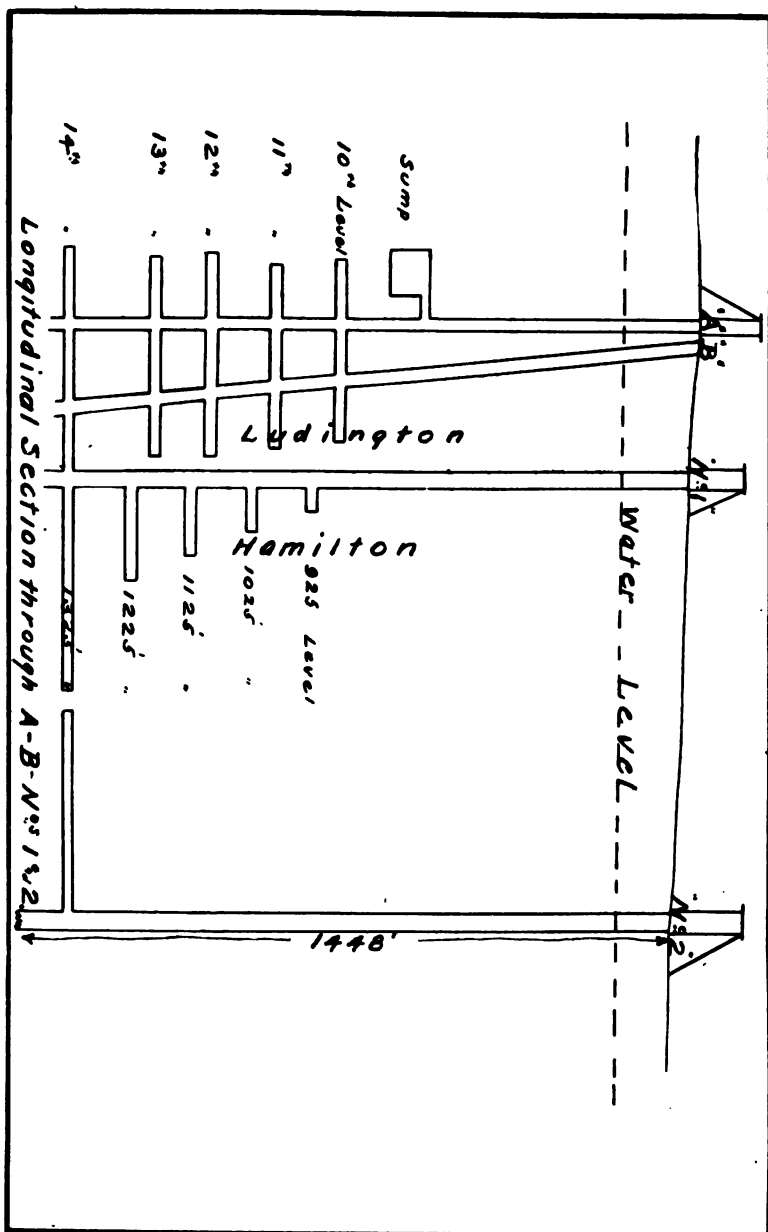
Note.—A single determination can be made by this method in from 20 to 25 minutes. The method is used when quick results are desired or when time is limited, and has been found to give satisfactory results with the Republic (specular and magnetic) ores. Sufficient work has not been done with other ores to warrant the advisability of its use generally.

THE UNWATERING OF THE HAMILTON AND LUD- INGTON MINES.

BY JOHN T. JONES, IRON MOUNTAIN, MICH.

In September, 1891, the Hamilton mine at Iron Mountain, Mich., was sinking their No. 2 shaft on what I call a stunt contract. The men were working under a verbal contract, which lasted during the entire sinking of the shaft, and was as follows: They were paid company account, \$2.25 per day, up to fifty feet per month and for all progress made over fifty feet they received a bonus of \$1.00 per foot for each man. There were thirty men employed in the shaft and for the month of September received a bonus of \$67.00 each, which means that they sank and timbered 117 feet for that month. There had been a gradual increase each month from fifty feet at the start to 117 feet. The entire shaft was in dolomite of a chemical composition of 65% lime, 30% magnesia and about 3% silica and the ground was very hard on steel although breaking well with 45% powder. All was going merrily and the men were in expectation of beating the September record. The shaft had been sunk with barely enough water to do the drilling.

On the 22nd of October I noticed a commotion at the collar of the shaft, the men had just brought to the surface a miner named Biddick, who was just finishing the last hole in the series in the northwest corner of the shaft. Four cross-bars were lowered at the same time with two drills on each bar and as soon as the drills had finished the holes the bars were hoisted to the surface. All had been hoisted but Biddick's when he struck into a vug, the water came out with such force that Biddick was tossed like a ball and was brought to



the surface blinded and nearly dead. Capt. Carbis and myself got on the bucket and after giving orders to the engineer to hoist to the surface on the first stroke of the bell, went down. All that could be seen was a water spout boiling through the mass of water. The drill and cross-bar are still in the bottom of the shaft 1,448 feet from surface.

Fig. 1 shows 24 holes, the eight end holes being perpendicular, the next row at a slight angle and the centre cut holes at about 60 degrees. The whole series were drilled, then all were plugged with turned plugs except the eight centre cut holes, these holes were first blasted and mucked out, then the angle holes were blasted and mucked and then the end holes.

Toward evening Mr. Banks, the superintendent of the Ludington, came to me and said he was much obliged to me for taking the water from the sump in "A" shaft, the water going to No. 2 Hamilton. The water continued to raise in No. 2 until it came within 90 feet of the collar of the shaft. We were at that time installing the 10-ton hoisting plant and decided to put in bailers to see if the water would abate. We were working at this plant when, on the 31st of December the hanging wall of the Ludington began to move and the water came into the eleventh level of the Ludington. The water was measured and was running at the rate of 6,000 gallons per minute. This drowned out the Ludington and filled the No. 1 Hamilton. The Ludington made futile attempts to get the water down until February 6, 1892, when they pulled the pumps and abandoned the mine. The water then rose until it reached the water level in No. 2 shaft.

At this period negotiations were tried to have both the Hamilton and Ludington take care of the water jointly. Not being able to agree on any proposition Mr. Kimberly bought a controlling interest in the Ludington, the minority agreeing to form an unwatering pool and divide the expense pro rata between the two companies according to the holdings of the stockholders. It was the opinion of most of the stockholders that the water came from a vug or cavern and after emptying

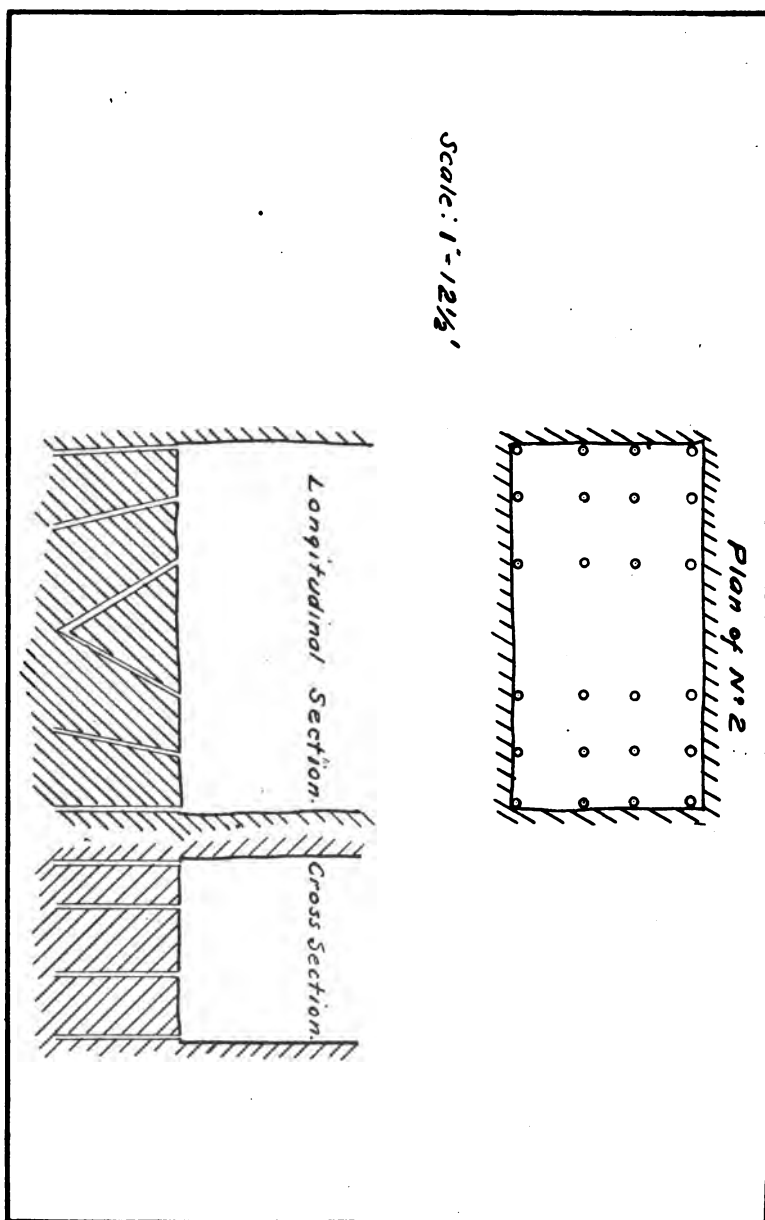
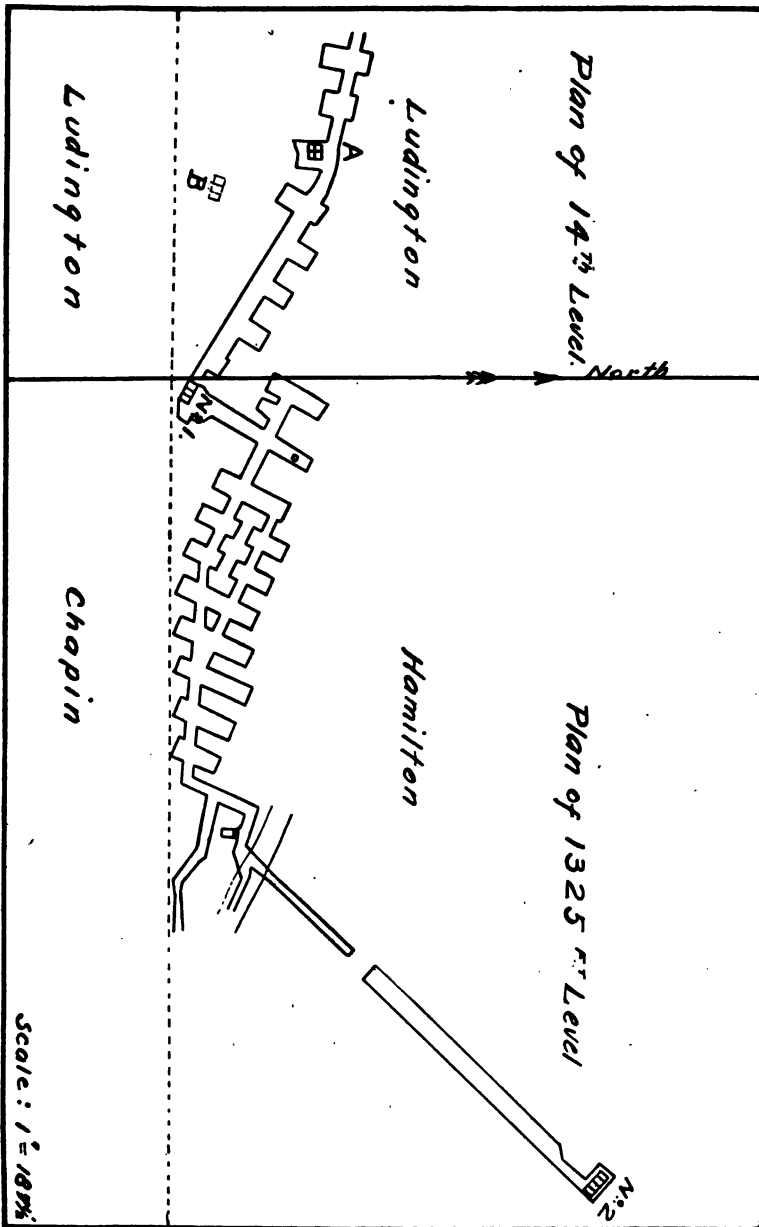


FIG. 1.



would abate and assume the normal flow. All were of the opinion that if the flow of 6,000 gallons was constant the properties would be valueless.

By June, 1893, the five shafts were equipped with bailers of a total capacity of 8,000 gallons per minute. Before starting we had to connect the 1,325 foot level of the No. 1 Hamilton with the No. 2 on account of No. 2 having a bailing capacity of 2,560 gallons in each of its two large bailers or ten gross tons per trip, and two other bailers with a capacity of 500 gallons each. On April 1st, 1892, we made a test of the bailers in No. 2 and found that we could keep the water by running about one-fourth of the time. We then closed down until we finished negotiations.

We had made the opening to connect with the 1,325 foot level at No. 2 and had started a cross-cut from No. 1 towards No. 2 leaving a distance of 275 feet to connect the two shafts. This connection would have to be made through No. 2 and the question arose what would be the danger to human life when it came to the time to put in the final shot that would bring the water. It was decided to drill advance holes, one centre hole and four angle holes 28 feet deep. (Fig. 2). Mine surveying has been reduced to a science but when life is at stake it takes great faith to put men in danger. So we were compelled to take additional precautions in these holes. We started these "feelers" when within 50 feet of the breast in No. 2 cross-cut. The pressure of water at this level is practically 600 pounds to the square inch or 43 tons per square foot or a total of 6,000 tons against the face of the drift. When within fifty feet of the water the drift began to wrinkle, causing a continuous shower of limestone flakes to fall from the roof of the drift. This was the time it tried the men but Captain Carbis and his men never flinched. They kept working until one of the drills struck through.

The expectation was that water would come but it was compressed air that had been driven ahead of the water when it came into the Ludington. When the drill was released from

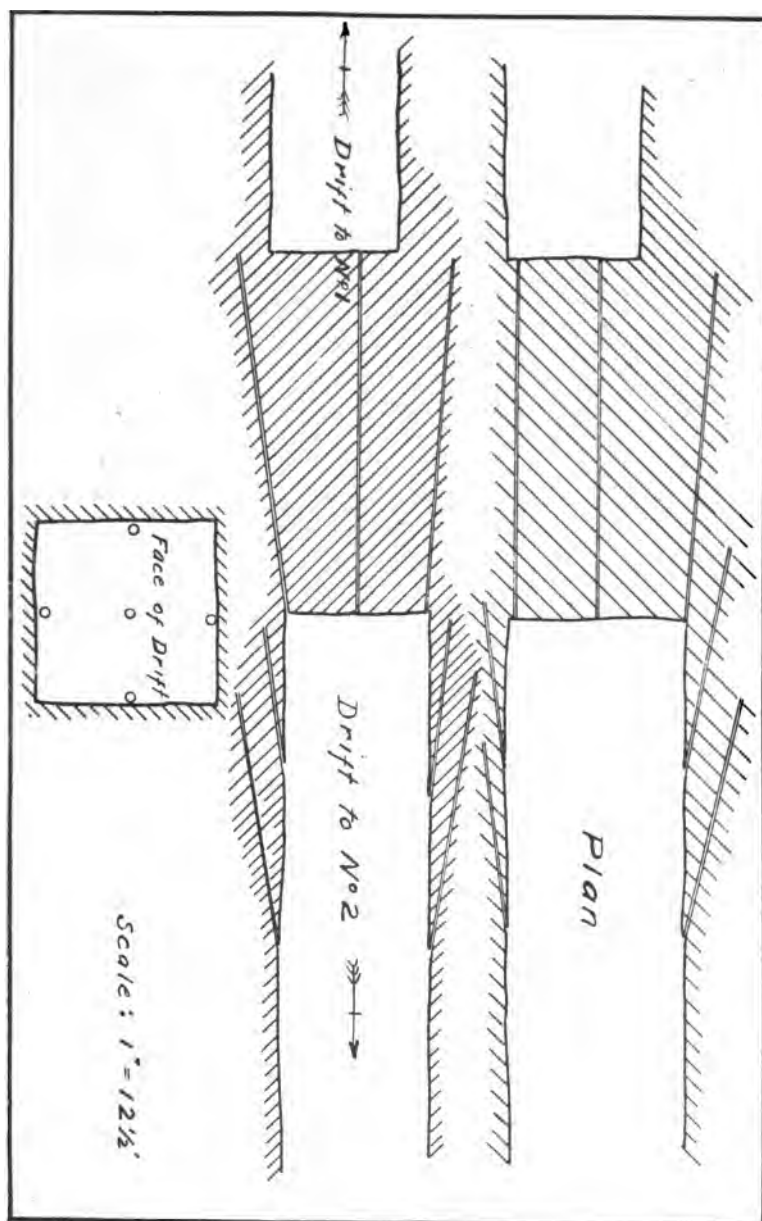
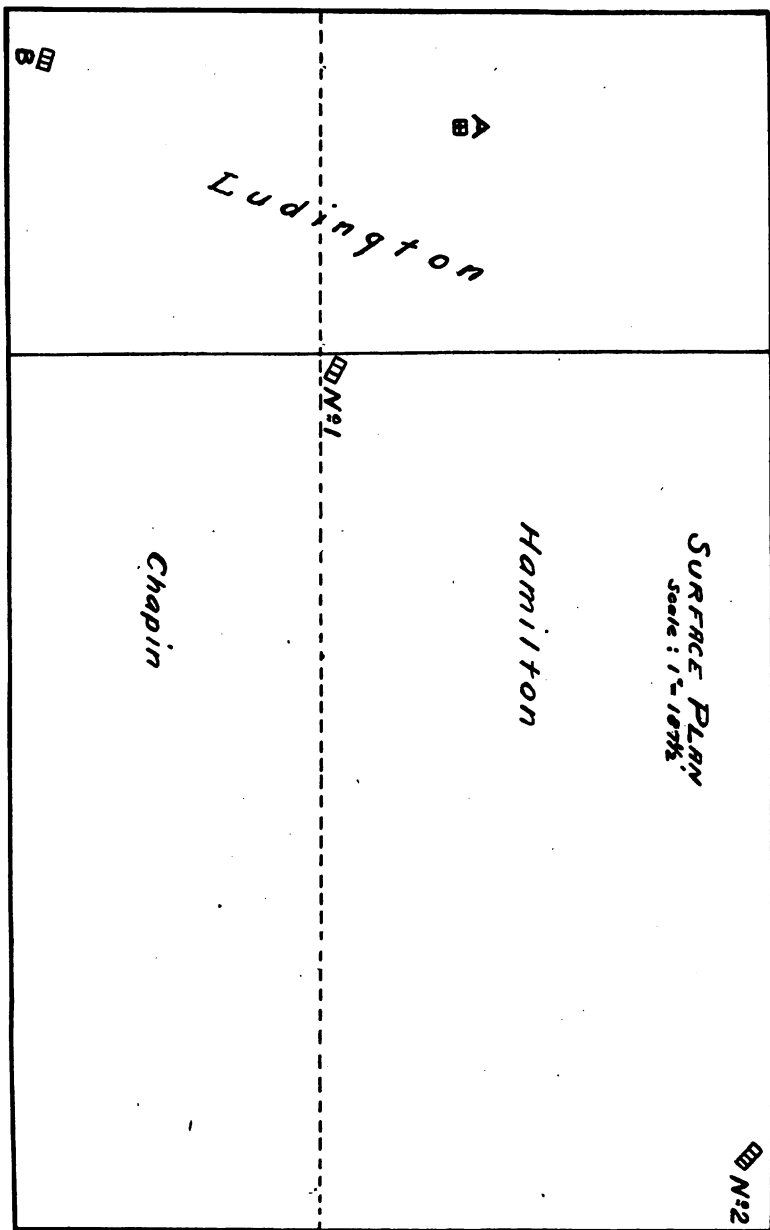


FIG. II.

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the chuck it went out of the hole like a ram-rod out of a gun and struck the side of the drift and bent like a bow. The remaining holes were then charged and fired. After the blast the captain let a box down with candles and found the barrier was still unmoved. He then recharged all the holes and tamped them and fired again. This time the water came up the shaft faster than a man could climb and the feat was accomplished without the loss of a life.

The bailers were then put in operation and in 21 days had lowered the water 896 feet hoisting fifty-four million gallons with the large bailers of No. 2 Hamilton and ten millions with the small bailers of the same shaft, four millions from the Ludington A shaft, eleven millions from the Ludington B shaft, six hundred thousand from Ludington No. 5, and pumping four millions with a Cornish pump making a total of eighty-seven million gallons in twenty-one days. The flow was then normal and in six weeks the water was out of both mines. After reporting to Mr Kimberly I received a message saying, "Have Jim MacNaughton measure the water and shut down after he reports the flow normal."

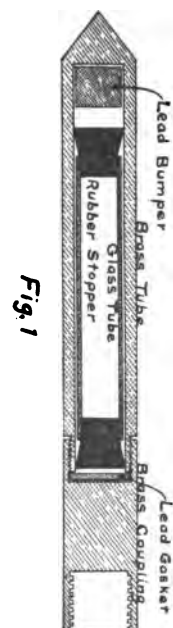
In conclusion I would advise any one undertaking a like job to drill diamond drill holes at least 75 feet ahead and tap the water with enough holes to lower it.

DETERMINATION OF ANGLES OF DIAMOND DRILL HOLES.

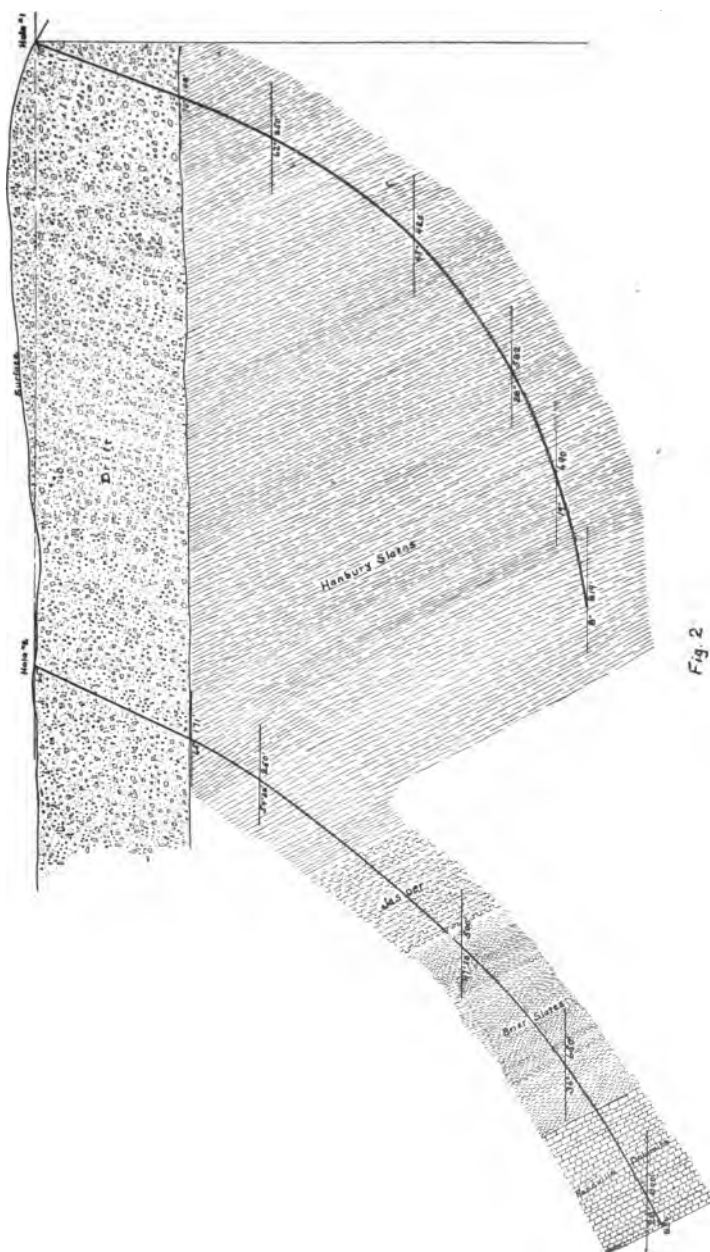
By F. A. JANSON, NORWAY, MICH.

I have been requested to show the Institute the result of our experiences in determining the angle of diamond drill holes. I wish to state, however, that with the exception of the method of enclosing the glass tube, I have nothing new to add to Mr. J. Parke Channing's paper entitled "Curvature of Diamond Drill Holes", which he read at the annual meeting of the Institute in 1894. (Vol. II.) In making our determinations we have simply been following out Mr. Channing's ideas.

Since 1894, little if anything, has been heard of surveying drill holes until recently. I have read some reports of tests made in South and West Africa, but no case has come to my knowledge in the Lake districts.



About two years ago Penn Iron Mining Co. decided to do some diamond drill work and knowing the tendency of holes to change angles, we determined to apply Mr. Channing's process of testing our holes. Seeing that Mr. Channing had considerable difficulty in keeping the water out of the tubes, we constructed a metal tube or cartridge, (Fig. 1), in which we enclose the glass tube, thereby relieving it entirely from pressure. We first made the cartridge of iron and intended to lower it into the hole by a heavy wire. It was found, however, that it could not be lowered in this way, as the casing had become



magnetized to such an extent as to make the cartridge stick to the pipe. This difficulty could, of course, have been easily overcome by making a cartridge of brass, which we afterwards did, but we finally decided to use the drill rod in lowering the cartridge, thereby entirely eliminating all danger of loosing it from the breaking of the wire.

In making a test, we take to the drill shanty a small bottle, previously coated inside with paraffine, filled with hydro-fluoric acid diluted to a strength of from 25% to 30%. An inch or more of this acid is poured into a glass tube, one inch in diameter by about six inches long, the ends of which are closed by rubber stoppers of size to fit snugly the inside of the cartridge. The glass tube is pushed into the cartridge, the latter screwed to the rod and lowered into the hole in the usual way. One hour to one hour and a half is generally sufficient to give a good etching.

As a rule most of our drill holes show a tendency to flatten. An example of this is seen in holes Nos. 1 and 2 east of

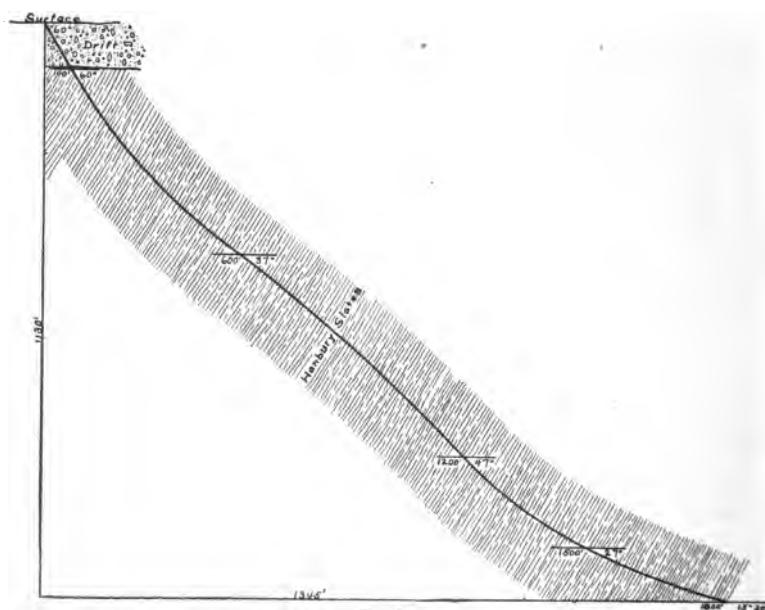


Fig. 3

Loretto, (Fig. 2), where No. 1 hole flattened out from 70° to 80° in a depth of 819 feet. This, however, is not a general rule as I have noticed reports of drilling in West Africa, where the tendency of deflection has been entirely the other way. Sometimes it even happens that, after a hole has commenced to flatten it will gradually change to a steeper grade and then flatten out again. Such was the case with a hole on Section 7, west of Norway, as shown by cross-section, (Fig. 3). The curves between observation points in this hole are somewhat imaginary. It shows, however, that the angles have been entirely reversed.

The deepest observation made by us is 1,800 feet. We found the etching at that depth as clear as observations taken closer to surface. I therefore, see no reason why this method cannot be used to considerably greater depths.

The determination of the lateral deviation of drill holes, if there should happen to be any, is a problem that has not as yet been solved. The local attraction prevents the using of a compass as proposed by some. Even if there was no attraction, I doubt very much if it would be sufficiently accurate to be of any practical value. I have read a report of a survey of some deep bore holes at Johannesburg, South Africa, where a needle was used. The report says that out of 23 readings five were wholly erratic. Of the 18 remaining readings, those taken at the same point varied from 2 to 45 degrees.

NOTE—The item 80° on second line of this page (151) should read 8° .

CARD SYSTEM OF ACCOUNTING FOR MINING SUPPLIES.

BY W. M. JEFFERY, DULUTH, MINN.

In beginning an outline of a method of accounting for mining supplies, we have in mind the excellent paper on this subject by Mr. Denton, and the consideration it has received in other papers, on accounting methods, that have heretofore been submitted to this Institute and embodied in its records. It would seem, therefore, almost needless to attempt to add anything to what has already been presented. However, it seems that this matter is of sufficient interest to some members of the Institute to cause them to request additional discussion along this line.

When we take into consideration the fact that our mining supplies constitute, approximately, thirty per cent. of the cost of producing our ores, it is not to be wondered at that operators are deeply interested in the methods of accounting for such a large percentage of the producing cost.

There has been almost an endless amount of thought and energy expended in endeavoring to protect pay rolls, or the labor portion of producing costs, and we regret to say, without resulting in a system that gives the employer absolute assurance that his pay rolls are free from error or manipulation. As we have just stated, then, it is not surprising that considerable thought and energy is being expended in endeavoring to perfect the method of accounting for our mining supplies, and while the following outline may be of benefit to some, we trust that it will, at least, be of interest to all.

The first duty of an individual, a co-partnership or a corporation, when they have a valuable asset, that has to be in-

trusted to the care of an employee, is to select a person who has the ability and the honesty to take good care of and account for such asset. There is no one who will dispute the fact that mining supplies is an item of great importance at all mines. A large amount of capital is required to be invested continually in material necessary for the operation of our mines, and sufficient material must be on hand at all times to assure the continuous operation of a property. It would be false economy, surely, to allow the stock of material in our warehouses to reach a point where operations would have to be delayed, awaiting the receipt of material. On the other hand, an excess stock, needlessly tying up capital, must be guarded against, and the oldest stock should be worked off, whenever possible, to prevent its becoming obsolete.

To accomplish the result of having our material account well guarded, and to keep our investment in material at the lowest point consistent with economical operation, some of the mining companies have adopted the plan of general warehouses; that is, where a mining company owns several mines in one locality, although the mines may be separated by considerable distances, they have a warehouse as centrally located as possible where the entire stock of supplies for all mines is carried. This plan, in the first place, necessitates but one warehouse man with special ability for this work and saves the cost of having a man of this class at each mine. Clerical work of the warehouse can be done by cheaper labor under the direction of this one man. In the second place, this arrangement permits of carrying a smaller stock of supplies than would otherwise be possible. It is unlikely that a similar part of any class of machines will break at all mines at the same time, and one or two spare pieces carried in stock will guard the interests of all mines in the vicinity, whereas separate warehouses at each mine, under different warehouse men, would in all probability each have a part for a similar machine, for the reason that the warehouse men would possibly not be in close touch with each other. The extent of our stock of mining supplies is reduced, by the

plan of central warehouses, cannot be realized by one who is not thoroughly familiar with supply work.

To digress somewhat from the accounting phase of the subject, we would state that a great saving in the quantity of supplies necessary to be carried can be accomplished by using, as much as possible, uniform machinery at the various mines. This is especially true in the case of power drills, steam shovels, pumps, etc.

Taking up the question of the man who should have charge of the warehouse. No merchant, who does not give his personal attention to his business, would think of employing a man to look after his stock for him in whom he did not have implicit confidence, and whom he did not know as one having an extensive experience in his particular line, nor would he think of offering such a man a salary that would not enable him to have all of the necessities and some of the luxuries of life, and thus eliminate, as far as possible, any temptation there might be for his employee to increase his income by giving some of his attention to a "side line", or possibly in other ways more injurious to the employer's business.

There is stock in some of the mine warehouses in this mining region with a value of from \$50,000.00 to \$150,000.00. There should not be the slightest hesitation on the part of operators to select with care a man who is to take charge of this investment for them and to pay him wages commensurate with the duties and responsibilities which are his. If this is done, operators can rely on it that they are receiving value for their expenditure. They can also rely on it that investment in supplies will not be larger than is absolutely necessary; also that a system of accounts will be evolved which will not only give a correct and satisfactory distribution of supplies used, but will also give, whenever it may be desired, a satisfactory and accurate inventory of material on hand.

The warehouse systems some few years ago were almost as numerous as the warehouses. During recent years, on account of the combination of various companies' interests, we

have all had a very good opportunity of becoming familiar with the various systems and of studying this subject with a view to uniformity. We consider the following one of the most satisfactory systems that has come to our notice.

Invoices, covering purchases, are received in duplicate and are sent to the person ordering the material to be approved by him as to price, point of delivery, terms of purchase, etc. As soon as the invoices have this approval they are forwarded to the point to which the supplies are consigned. When the mine office receives these invoices, the duplicate copy is sent to the warehouse for approval as to the receipt of the goods, the original copy being retained in the mine office until the duplicate is returned to them by the warehouse man, at which time he signs the original invoice, indicating that the goods have been received at the warehouse. The original bill is held in the mine office while the duplicate bill is in the warehouse, in order that the chief clerk at the mine office may know at all times what bills have been referred to the warehouse which have not been returned to him. In this way he can watch cash discounts on bills and see that the warehouse does not hold the invoice beyond the discount period and thus lose the discount privilege; he can also have a check on the warehouse to see that they do not lose any of the invoices turned over to them for approval. It frequently happens that material does not reach the warehouses until after the discount period has passed. In such cases, the mine office forwards the invoice for payment, prior to the receipt of the goods, in order not to lose the discount privilege, where the invoice is from a well established firm. In such cases a notation is made on the invoice that the goods have not yet been received, and the treasurer uses his judgment in paying such invoices prior to the receipt of the material. Very little, if any, risk is taken in doing this, for the reason that, almost without exception, the houses from which material is purchased would promptly and gladly make good any lost or defective material, and the gain in taking advantage of cash discounts is something that should not be overlooked. As soon

as both original and duplicate invoices are approved, the mine office forwards them for payment.

The warehouse records consist of a freight received book, a box of supply cards and a supply of debit and credit slips.

As material reaches the warehouse a record is made in the freight received book (Figure 1) showing date received, name of railroad, pro number, and amount of freight charges; also consignor, date of invoice, articles received, quantity received, our number of invoice, date invoice was received, the date the invoice was approved, and any remarks that may be found necessary. This book, in addition to being a valuable record of freight received, guards against passing an invoice for the same material twice. It can readily be seen of how much assistance this record is to the warehouse man in cases where goods are received prior to the receipt of an invoice. It is also a great assistance in checking freight bills, where the freight bills are not received at the same time at which the goods are delivered. We find that this latter frequently happens.

The supply cards (Figure 2) are about 8"x12" in size and are ruled in ledger form. The debit side shows the date of invoice, our invoice number, consignor, quantity, price and amount. The credit side shows date, account for which supplies were used, quantity, price and amount. We use one of these cards for each grade or size of each class of supplies; that is, we would have one card covering 40% powder, another card for 60% powder, one card for 1" elbows, another card for 1½" elbows, another for 2" elbows, etc. As soon as the duplicate invoice, covering material purchased, reaches the warehouse and is approved as to receipt of material, the warehouse man charges on his supply cards, direct from the invoice, his various classes of supplies. The amount of freight is also charged on each card, covering material which is entered thereon. The division of freight is made, in cases where there are a number of items received in one bundle, in accordance with weight of the various items. Probably all warehouses have a record of the weights of various fittings and other commodities

that are liable to be shipped in one bundle, and the division of freight is made, based on these recorded weights. Each card, then, represents the cost of the various items of supplies delivered at the warehouse. The question of cartage will frequently arise. Where material, necessitating considerable cartage, is received for a specific purpose, it is usually a small matter to apply the cost of the cartage directly against the material hauled, for the reason that it is usually of considerable bulk. However, when a team is sent to the depot and brings to the warehouse a miscellaneous assortment of supplies, and possibly does other errands on its way to or from the freight sheds, it has not been the custom to attempt to put the cost of cartage, in such cases, against the cost price of supplies, but such expense has been prorated to the operating cost accounts in proportion to value of supplies used, or absorbed in a general surface cost account, which latter is considered as just a disposition as can be made of these small charges. The cost of operating the warehouses is not added to the cost of mining supplies. It is treated as a separate cost account, just as office expense is treated as a separate cost account.

In determining the cost at which supplies should be charged to the operating accounts, two methods can be used: first, an average cost of each size or grade of mining supplies on hand can be obtained by dividing the total value, as shown on the debit side of the respective supply cards, by the number of pieces on hand; second, by using the price of the oldest supplies on hand until all items at that price have been consumed; then use the price of the next lot until they are consumed. It would be very unusual to have more than two different prices on any one size or grade of material in stock at once. We prefer this latter plan, for the reason that the stock then always stands at the very latest price that we have, and with the card system it is not difficult to tell what quantity is on hand at the old price. After the invoices have been recorded on the supply cards at the warehouse, they are then turned over to the mine office, as previously outlined, and this completes the receipt of supplies.

The debit and credit slips are records covering the disbursements of supplies. The debit slip (Figure 3) is a form about 8"x11" in size, with a printed heading indicating the mine at which the supplies are used, the week during which the supplies are issued, and the *cost account to which the supplies are being charged*.

The credit slip (Figure 4) is a form of the same size as the debit slip, and having a printed heading, indicating the mine at which the supplies are used, the week during which the supplies are issued and the *class of supplies that is to receive credit*.

Now let us take up the disbursement of supplies. No supplies are issued from the warehouse without an order from the superintendent of the properties, or from someone authorized by him to issue orders on the warehouse. These orders, in addition to stating the items of supplies required, show for what account they are to be used, and are signed by the superintendent, or foreman issuing the order.

As the warehouse man has opportunity, the material covered by these orders is entered on a debit slip. One of these slips is used for each cost, construction, improvement, or other account that it may be deemed necessary to keep, and all articles of supplies used for each account are shown on the respective debit slips for the account indicated by the order on the warehouse for the material. There are seven columns on this form, one for each day in the week. These columns are for the purpose of saving extensions. If there are 100 lbs. of powder delivered for stoping on Monday, the grade of powder is noted in the article column on the stoping card, and the weight entered in the first column. If 100 lbs. are delivered the next day, the article will not have to be entered on the debit slip the second time, but the weight is placed in the second column and so on for the weight of that particular grade of powder delivered for each day during the week, at the end of which time the sum of the weights for the six or seven days is extended in total quantity column, the price being filled in and extension made.

This means an extension once a week for each size of each kind of supplies used for each account. At the end of each month a summary of these debit slips is made, to show the total supplies charged to each of the operating, construction or improvement accounts. This summary consists of adding together the weekly totals chargeable to each account.

In addition to entering these orders for material on the debit slips, as outlined above they are entered also on the credit slip, in accordance with class of supplies that was delivered. A credit slip is kept for each of the different classes of mine supplies; that is, one for explosives, one for candles, another for oils, one for iron and steel, etc. In entering the orders on these credit slips, the items are entered by grades or sizes and the same plan is followed in regard to collecting the number of pounds or pieces of each grade or size delivered during the week, as is followed on the debit slips. A summary of these credit slips is made each month to show the total of each class of supplies used during the month, which is accomplished by adding together the totals of the four or five weekly credit slips. The total of the credit slips for a given period must equal the total of the debit slips for the same period, showing that the articles and values charged to the cost accounts, agree with the articles and values that are being credited to the supply accounts.

From these credit slips we obtain the information necessary to complete the credit side of our supply card. Each grade or size of each class of supplies is shown separately on the credit slip and we obtain, as shown above, the total of each for a week, and this total can readily be transferred from the credit slip to the credit side of our respective supply cards. It is deemed advisable to have these transferred to the supply card at least once a week, in order to have the supply card show more accurately the actual inventory on hand. If it were allowed to run for a month, the card would be of little value until the month's work was entered.

This completes the warehouse records covering disbursements of supplies.

The supply cards can now be footed and balanced, showing the quantity and value of each kind of supplies on hand. The warehouse records are not duplicated in any way in the mine office, although from our mine office books we can check the correctness of the warehouse records in the following way:

The mine office has an invoice or an audited voucher record with a debit and credit page, each divided to provide for a total and for twenty-seven different classes of supplies. At the first of each month the inventory at the close of the preceding month is brought forward onto the debit page of this record. Each invoice, after it is approved and passed for payment by the mine office, is entered on the debit side of this record and the value of the items thereon distributed into the proper columns. As soon as all invoices for the month are entered; and it will be borne in mind that the warehouse records and the mine office records close with the same invoice; the various columns in this record are footed and balanced across with the total column. These footings give, of course, the inventory at the close of the preceding month of each class of supplies, plus the additions of each class of supplies during the month, and were there no supplies consumed, this would represent the inventory of material on hand. However, as soon as the warehouse has their debit and credit slips completed and balanced for the month, and have taken the necessary record on the credit side of their supply cards from their credit slips, the debit and credit slips are sent to the mine office, together with a summary from each, which has been prepared therefrom, as shown above. The mine office, from these summaries, makes their journal entry, crediting each of the twenty-seven classes of supplies, as per summary of credit slips, and charging, from summary of debit slips, each operating, equipment, or other account which has been found necessary to keep.

This journal entry, in addition to passing through the journal as to totals, is entered on the credit side of the mine office invoice record in detail. The difference between the debit and credit pages of this record will now show the book inventory of each of the twenty-seven classes of supplies on hand.

**DATE
RECEIVED**

CLASSIFICATION.

CLASS No.	AMOUNT	
101		
102		
103		
104		
105		
106		
107		
108		
109		
110		
111		
112		
113		
114		
115		
116		
117		
118		
119		
120		
121		
122		
123		
124		
125		
126		
127		
Total		

(This form is printed on back of
blanks marked Figs. III and IV).

While the mine office keeps but twenty-seven divisions of supply account, the warehouse has in its supply card record a large number of subdivisions of each of these classes. Once a month the warehouse furnishes the mine office with a balance sheet, which shows the amount of each of the twenty-seven classes of supplies on hand at the end of the month, according to their supply cards, and these balances the mine office checks against their balances, as shown by their invoice record. This balance sheet is made up by adding together the balances shown on all cards in the warehouse going to make up a subdivision on the mine office record. For instance, the warehouse may have twenty-five cards, covering different sizes of iron and steel and the total of all of these twenty-five cards will be required to make up the balance of the iron and steel account in the mine office record. If the warehouse records are not in agreement with the mine office records on any of the various classes of supplies, the work must be checked up and the trouble located and corrected.

In addition to this check on the warehouse as to correctness of their records, we have, of course, the actual inventory, and the balance of no kind of supplies can be in error for any length of time, because the warehouses keep continually checking the actual inventory of material on hand with the card inventory, and if any discrepancy exists it is readily located and adjusted.

While this matter of checking actual inventories with card inventories is being continued at every opportunity, it is done especially when a new supply of any class is being ordered. This, for the purpose of knowing that it is absolutely necessary to order the supplies, and also because, when the stock is almost exhausted, it is the most convenient time for making an actual count or taking the actual weight of any material.

It may be contended that in using cards and the debit and credit slips, there is a possibility of some of these records being lost. This, of course, is a contingency that must be met with in all loose leaf records, and is well guarded against by having

proper binders, both in the warehouse and for filing in the mine office.

The benefits to be derived from a system of this kind are many and we will mention but one or two of the principal advantages. The first of these that we would mention is the fact that we are enabled to get a correct supply cost on our cost sheets, by being able at all times to know absolutely the cost of each article of supplies, because the inventory is so well guarded from leaks of different kinds, it is not necessary to add to our supplies consumed a percentage of profits to make up for any possible loss in the handling of supplies. If a cost sheet is to be of any use to an operator, it must be accurate, otherwise it is misleading rather than beneficial. Anything, therefore, tending to improve the cost sheet is of great benefit to the operator who is responsible for the cost of producing ore.

The next in importance is the benefit of having the supply records in a condition where the warehouse man knows absolutely what he has in stock and can be governed accordingly in making requisitions on the purchasing department for additional supplies, thus keeping down the investment in mining supplies to the lowest point consistent with good operating.

Another important advantage in a system of this kind is the readiness with which an inventory may be arrived at, at the end of the year, or for that matter at any time during the year. All are familiar with the task of taking a complete inventory at the end of each year, when the weather conditions are very unfavorable, when no one knows just how the supplies are going to come out, when the closing work of the year makes it hardest to spare the necessary time, and when the time for taking the inventory is necessarily limited. If this system is carried out as it should be and the cards checked continually with the actual material on hand, there should be no hesitancy about taking the card inventory at the end of the year as being actual.

The benefits of a system of this kind would increase in direct proportion to the quantity of supplies necessary to be

carried in stock or volume of supplies consumed. If the stock of supplies at any point is sufficiently small, so that the warehouse man can take a complete inventory of them quickly and accurately, a system of this kind would not be of the same advantage as it would in a case where the stock of supplies is too large to permit of an inventory being taken in this way.

With the continued centralization of interests, the general warehouse idea will undoubtedly be given more attention than in the past, and, as these general warehouses increase in number, a revision of the old warehouse systems will have to be made to meet the requirements of the new conditions. It was with this in view that the system which has just been outlined, has been adopted by some mines. It is true that it will cost a little more to use a system of this kind than it would to use some of the older and simpler systems in vogue, but the additional labor necessary should not be judged by the amount of detail which it would appear is necessary from the above. It usually takes longer to explain how a piece of work ought to be done than it does to do the work when you know how, and we have found this is especially true of outlining a supply card system, as you will all, undoubtedly, be willing, by this time, to admit. It will be found that the advantages of such a system more than offset any additional labor that may be necessary. The additional cost will be found comparatively small, and it is always quicker and more economical to do a thing right than it is to do a thing wrong.

A METHOD OF SURVEY FOR SECONDARY MINE OPENINGS.

BY FLOYD L. BURR, E. M., VULCAN, MICH.

One of the problems encountered by most mine surveyors has to do with the location and alignment of those mine openings which, from the surveyor's point of view, might be termed "Secondary Openings". These "Secondary Openings" are chiefly raises, winzes, and stopes, but often include short or crooked drifts more or less remote from the principal workings, or only with difficulty accessible from the regular levels. It is not to be implied that these places are unimportant, for indeed they are often-times of the very greatest importance in the exploration, development, and mining of ore. It is not usually necessary to make elaborate surveys of these places, determining azimuths and distances with the same degree of accuracy as is required for the general survey of the mine, but it is often essential for various purposes that these secondary openings be located with *some* approximation to exactness. For geological purposes this approximation may be very rude while for holing problems a much closer approximation is required. The method which I am about to describe is offered as a substitute for the transit in the survey of these "Secondary Openings", wherever and whenever its degree of precision is sufficient for the purpose in hand. Its degree of precision seems to be sufficient for many purposes even including some holing problems of minor importance.

Of course all this work can be done with a transit in the usual way, and I believe most beginners would be inclined at first to do it in that manner. In the great majority of cases, however, the use of the transit in such places involves so much danger to man and instrument, so much general difficulty in

taking steep sights, and so great an expenditure of time in the building of stagings, and in the setting up the instrument in cramped, wet dirty places, that it is impracticable.

If hand instruments be resorted to, the angle in the vertical plane offers no difficulty as almost any clinometer is capable of giving sufficiently close results. But the matter of the azimuth is not so easily disposed of. Usually the compass is pressed into use and occasionally with good results, but it is not reliable. In working around these cramped, crooked places one cannot readily eliminate the magnetic effect of pipes, drills, etc., which are generally present and often hidden.

Having encountered a goodly number of these problems, I have finally settled upon the following scheme which I believe, serves the purpose better than any other. As far as I know, no one else has ever tried it exactly in this form. At any rate I believe that it is new in its application to the determination of the *horizontal* angle in *inclined* openings. The idea is an outgrowth of the old Cornish method of stretching wires or strings from one point to another and hanging compass and clinometer from these strings, thus determining the magnetic bearings and the vertical angles of all the lines. This method is cumbersome and has the same old inherent fault of depending upon the magnetic needle. I believe further that it would be difficult to use it on lines steeper than 30° or 40° .

My plan is to stretch a strong smooth string (wrapping twine 1-25" diameter) from one point to another, taking in usually, at one setting all points of the proposed traverse. The angles between the portions of the strings are determined by measuring with a steel tape line from the vertex out to each of two "riders" placed one on each string at suitable distances out, and then measuring across from one "rider" to the other. (See figure I). It is obvious that by this "triangle of measurements" (a, b, and c,) the angle (C) between the strings is determined and it only remains to lay it out graphically or compute it in the office. When the angle is in an approximately horizontal plane, as would usually be the case in the survey of a drift, there is nothing more to be done, since (C) is the required

horizontal angle. However, it is not in this simple case that the method is most valuable. In the general case when one or both legs of the angle are inclined, as in the survey through winze or rise, the angle (C) will be in an inclined plane, and

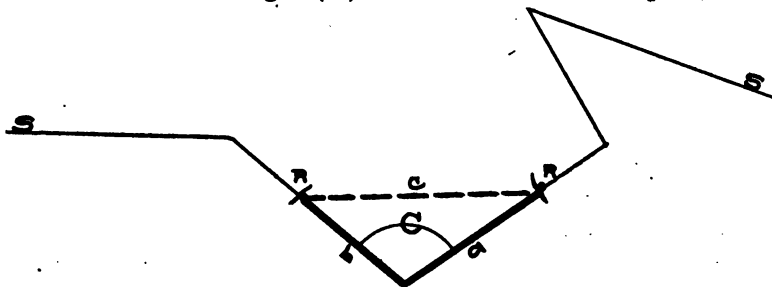


FIG. I

further observation is necessary in order to determine (D) its horizontal projection. This angle (D) is a function of (C) and of the vertical angles (A) and (B) of the two inclined strings. We must therefore measure (A) and (B). See figure III. This may be accomplished ordinarily by holding the straight edge of a clinometer such as Brunton's Pocket Mine Transit lightly up against the under side of the string and setting the instrument by successive approximations. When great accuracy is required these angles (A and B) may be determined by hanging a plumb-bob from the vertex or from a point vertically above it, placing a rider on the plumb-line and taking a "triangle of measurements" in the vertical plane of each string. This determines (A and B) in exactly the same way that (C) was determined. See Fig. II. Since this involves additional labor of laying out in the office, the use of the clinometer is preferable in ordinary cases where we do not need to push the method to its greatest degree of accuracy.

The string should be of a good quality of brown wrapping twine and should be wound on a suitable reel. A length of 300 or 400 feet is desirable. The "riders" mentioned are merely for the purpose of marking definite points on the strings during the two or three minutes occupied in taking the measurements. They consist of

three-inch pieces of No. 22 soft copper wire wound once or twice around the string tightly enough to prevent slipping. After the string has been stretched from point to point of the traverse these short pieces of wire are broken off from a spool

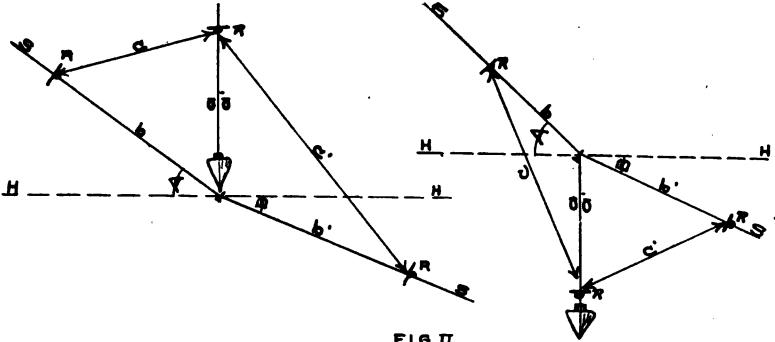


FIG. II

and placed at the proper places on the strings. As soon as the "triangle of measurements" for that vertex has been taken, the riders are untwisted from the string and thrown away.

Nails or spikes driven into the sides of drifts or raises or into convenient timbers, serve for points, the string being given one or two turns around the nail under the head. Care must be taken to have string entirely free between points. For maximum accuracy, the points should be so chosen that the angle (C) should never exceed 160° though very fair work may be done when it is somewhat greater. Obviously the farther the riders are placed from the vertex, the more accurate the determination of the angle C.

Generally the a and b distances are made about five or six feet, sometimes as small as three feet or as great as twenty feet, depending upon circumstances. Measurements should be taken very carefully and to the nearest 1-200th of a foot.

The intersection of the lines of the two strings is the vertex. This will usually be at the side of the nail when the string is properly arranged. It is best, at least when first using the method, to take two or more independent "triangles of measurements" for the determination of C by placing the riders at somewhat different distances for the different sets of

measurements. Thus one can judge of the degree of accuracy of his results and feel a corresponding degree of confidence in them.

Whenever the purpose of the work demands more than usual accuracy it should be possible under favorable circumstances to get results approaching those of transit work by taking an average result from many determinations. However extreme accuracy is not the province of this method and it would be rarely that one would care to force the method into the realm of instrumental work.

The higher the values of A and B (the vertical angles of the two strings) the less accurate the determination of D; consequently very high angles should be avoided even by increasing the number of stations in the traverse. 75° might be mentioned, as an arbitrary limit in steepness.

For special situations special arrangements of strings will suggest themselves to the experienced mine surveyor. With this method it is not necessary to avoid wet, dirty, smoky places and it is in just such situations that the method lends its greatest value.

The notes may be kept in any convenient form, but must record whether the deflection in the horizontal plane is to the left or to the right.

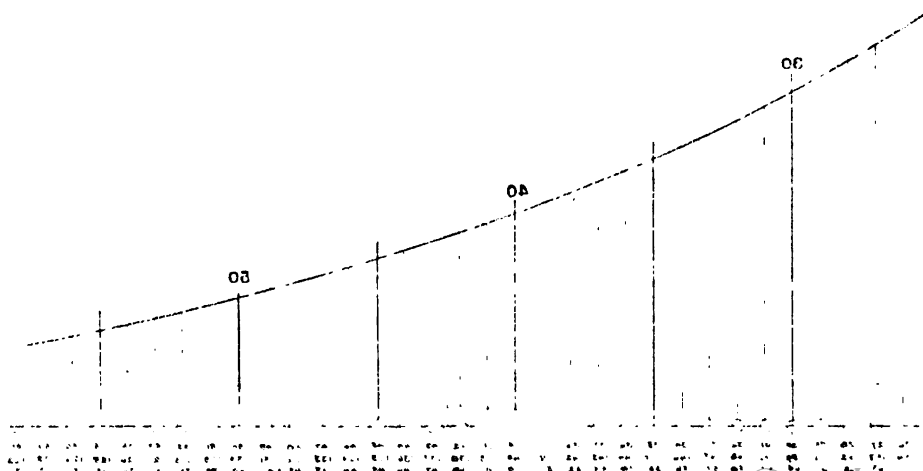
In the office the angle C is to be determined graphically by laying off the "triangle of measurements" to a suitable scale, say one foot to one inch, and measuring the resulting angle with a protractor. Occasionally it may be desirable to compute C by plane trigonometry. When C is in an inclined plane, it will be necessary to find D, the horizontal projection of C.

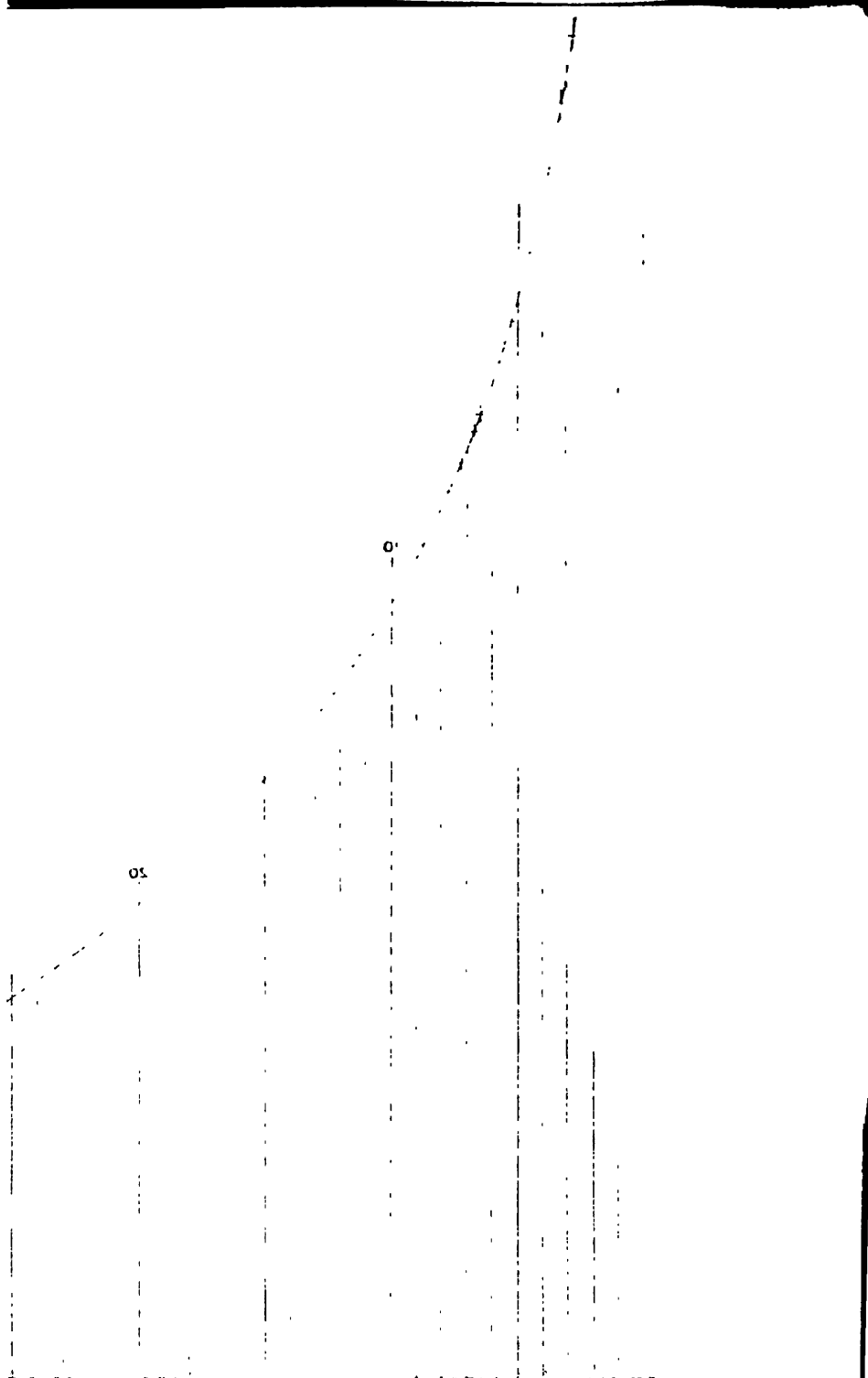
This may be done by computation or by graphics.

When logarithms are not at hand one may use the formula:

$$\cos D = \frac{1 - \sin A \sin B - 2 \sin^2 \left(\frac{C}{2} \right)}{\cos A \cos B}$$

A and B being the vertical angles of the two lines.





15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

For logarithmic computation spherical trigonometry gives the formula :

$$\cos \frac{D}{2} = \sqrt{\frac{\sin S. \sin (S-C)}{\cos A. \cos B.}}$$

S being equal to $\frac{1}{2} [C + (90^\circ - A) + (90^\circ - B)]$ taking into account the algebraic signs of angles A and B (See figure III.) This I consider the most satisfactory solution ordinarily.

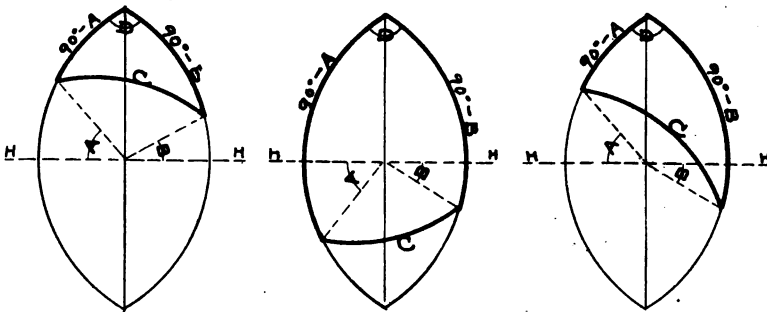


FIG III

From the same formula, the solution may be accomplished on the principle of the slide-rule by the aid of a curve or diagram giving the logarithms of the sines and cosines of all angles from 0° to 180° by lengths of lines drawn to a suitable scale. These lengths are taken off with a pair of dividers, and combined graphically according to the formula. This solution will be readily understood by those familiar with the principle of the slide rule. (See figure V.)

A satisfactory solution for ordinary work is by pure graphics. (See figure IV.) From the vertex of C as found graphically, lay off on each leg some suitable unit distance, as ten inches. Draw a horizontal line X — X and from some point o, draw o M and o N at angles of A and B. Lay off on each the same unit distance o m and o n. Through n draw X' — X' parallel to X — X and from m and n draw perpendiculars to X — X.

From m strike an arc with radius equal to "chord of C" intersecting X' — X' at some point P. Then from Q strike an

necessary for the work for which it is to be used. The time required is comparatively slight. With ordinary care, the horizontal angles may always be determined within one degree of the truth and often within ten minutes.

I append a tabular record of a test made under the usual conditions underground. Complete field notes and results are shown for the seven angles measured in the test; these were measured by the string method and checked by the transit. The errors were respectively, $-25'$, $+15'$, $+16'$, $+27'$, $+07'$, $+44'$, $+09'$, this is an average error of $20'$, or, considering it in another way if these seven angles had constituted a traverse, there would have been a net accumulated error of $+1^{\circ} 33'$ at the end of the traverse. For many situations this would be well within the requirements.

Field Notes.	TESTS.			
	1.	2.	3.	4.
c	9.925	5.020	12.380	8.245
a	4.035	5.755	5.750	4.490
b	6.980	6.990	7.015	5.135
A	0°	0°	$-41^{\circ} 15'$	$-41^{\circ} 25'$
B	$+37^{\circ} 50'$	$38^{\circ} 15'$	$+38^{\circ} 15'$	$+42^{\circ} 15'$
Results—Graphical.				
C	$126^{\circ} 58'$	$45^{\circ} 08'$	$152^{\circ} 11'$	$118^{\circ} 03'$
D	$139^{\circ} 47'$	$25^{\circ} 58'$	$142^{\circ} 52'$	$92^{\circ} 42'$
Computation.				
C	$126^{\circ} 29'$	$45^{\circ} 07'$	$151^{\circ} 38'$	$117^{\circ} 44'$
D	$138^{\circ} 50'$	$26^{\circ} 01'$	$143^{\circ} 02'$	$92^{\circ} 08'$
Transit Check Work.				
D	$139^{\circ} 15'$	$25^{\circ} 46'$	$142^{\circ} 46'$	$91^{\circ} 41'$
A	0°	$+38^{\circ} 25'$	$+38^{\circ} 25'$	$+42^{\circ} 31'$
B	$+38^{\circ} 25'$	0°	$-41^{\circ} 20'$	$-41^{\circ} 20'$
Inherent Error.	$-0^{\circ} 25'$	$+0^{\circ} 15'$	$+0^{\circ} 16'$	$+0^{\circ} 27'$
Field Notes.	5.	6.	7.	
c	9.070	8.920	10.560	
a	4.505	5.150	4.325	
b	5.135	4.480	7.475	
A	$-47^{\circ} 45'$	$+42^{\circ} 15'$	$-47^{\circ} 48'$	
B	$+42^{\circ} 15'$	$-35^{\circ} 15'$	0°	

Results—Graphical.

C	140° 31'		
D	122° 55'		
Computation.			
C	140° 18'	135° 37'	124° 50'
D	122° 54'	123° 18'	148° 15'
Transit Check Work.			
D	122° 47'	122° 34'	148° 06'
A	+42° 31'	+42° 31'	0°
B	-47° 42'	-35° 02'	-47° 42'
Inherent Error.			
	+0° 07'	+0° 44'	+0° 09'

Figure I shows the string passing from one point to another, the "riders" R R and the "triangle of measurements" (a, b, c,) for one station.

Figure II shows the situation when there are the vertical angles A and B. In addition to the "triangle of measurements" of figure I, the angles A and B must be determined either by a clinometer or by the additional "triangle of measurements" (a, b, c and a' b' c') involving the use of a plumb-line hung from the vertex, or from a point vertically above it. SS is the string, HH is the horizontal plane.

Figure III shows the three cases, A and B both above the horizon or positive, A and B both below the horizon or negative, and A positive with B negative. The sides of the spherical triangle are shown in the heavy lines; they yield this formula:—

$$\cos. \frac{D}{2} = \sqrt{\frac{\sin S. \sin (S-O)}{\cos A. \cos B.}}$$

Figure IV shows the various steps in the graphical solution of the problem by which is determined D, the horizontal angle from the quantities A, B, and C.

Figure V shows the logarithmic sine curve or diagram which may be used on the principle of the slide-rule to solve the logarithmic equation for $\cos. \frac{D}{2}$. The original is drawn to a scale of 10 inches to 1 unit in the characteristic. Thus the ordinate of $\sin. 30^\circ$ for example is about 6 inches long.

CARGO SAMPLING OF IRON ORES RECEIVED AT
LOWER LAKE PORTS—INCLUDING THE
METHODS USED IN THE ANALYSIS
OF THE SAME.

BY W. J. RATTLE & SON, CLEVELAND, OHIO.

We very willingly respond to the call of your secretary, asking for a paper, explaining the methods employed by chemists at lower lake ports upon the sampling and analyzing of iron ores, but regret that we cannot give you the methods used by other chemists and will endeavor to give you in detail the methods adopted by ourselves, which we have found to be the best and surest ones to use in the sampling and analyzing of all grades of iron ores.

With each succeeding year in the history of iron ore mining, the output has increased, and to meet this increase, the vessel owners have built larger and larger boats, until now, we have the modern ore carriers with enormous capacities. As the output has increased, so has the carrying, unloading devices, railways, docks, etc. With this progress from year to year, we have found it necessary to make changes in the method of sampling. Up to the time of the installation of the clam-shell, the sampling of boats was not such a difficult proposition—as at that time, boats were unloaded by shoveling the ore into buckets—the shovelers working down through the ore in the centre of each hatch, to the floor, and then working out, naturally gave good faces of ore to sample. With the slowness of unloading, the sampler found better walls of ore to sample and could take more time.

The method of unloading at present varies at nearly every dock—and consequently the method of procuring sample varies

accordingly—for example, at the Erie docks, Cleveland, where they have three clam-shells, the boats are clamped out until bottom is reached in all hatches, then the boat is shifted to the Brown bucket machines, and finished unloading by hand. In this case, we aim to sample the ore when the boat has left the clams.

At the Cleveland Furnace Co.'s docks, Cleveland, they have two Brown clam-shells that clamp out the ore until bottom is reached, when at once scrapers are put in and the ore between the hatches is scraped to the centre of each hatch, where the clams can reach it—and in this manner, the entire boat can be unloaded by the clam-shells, the sampler taking his sample from each hatch before the scrapers are used. On other docks, the above methods of unloading are used and in some cases, unloading by hand or buckets is used entirely. In all cases, the sampler obtains his sample when bottom is reached in each hatch, and by following out this rule, we obtain a good average sample—no matter whether the cargo is a mixture of several ores or not.

We all know that the greatest responsibility in doing this work lies in the sampling and to this we give our most careful attention, employing men that have a deep sense of honor and honesty—together with judgment and reasoning power. With these qualities, we give them the practical instructions and method of sampling here in Cleveland on the docks, before sending them to other ports to take charge of our work. We have been fortunate in keeping the same sampling force intact each season, and thereby lessening the chance for error caused by inexperienced men.

METHOD OF SAMPLING AT LAKE ERIE PORTS.

By the term "Lake Erie Ports"—we mean all the docks from Detroit, Mich., to Tonawanda, N. Y. Our method of sampling is the same at each and every dock along the above frontage. The necessary tools used in sampling are a large sized trowel, a hammer, and a wide-mouthed can, with a capac-

ity of about 45 pounds. With these the sampler enters the boat when bottom is reached, sampling every hatch in the following manner: Starting from one side, he goes around the walls from bottom to top, taking one-half a trowel-full of ore from every 18", the distance between his perpendicular sampling being 24". When lump ore is encountered, he takes a piece in bulk equal to the amount of fine ore taken on each trowel sample.

When he has filled his can, he dumps this upon a clean floor space in the boat, and proceeds sampling until each hatch has been sampled. After completing his sampling, he goes over his sample carefully, cracking up the lump, so that the entire sample can be homogeneously mixed together.

Our method of mixing the sample on the boat is by shoveling the ore from one pile to another, putting each shovel-full on top of the cone until all the ore has been delivered from one pile to the other. After repeating this several times, the pile is flattened out by placing one corner of the cutting edge of the shovel in the top of the cone and circling the pile. This distributes the ore evenly and at the same time flattens the cone. The flattened pile is evenly quartered and the opposite quarters are thrown out. The above mixing process is continued, and if found necessary, the lump ore is crushed finer, (this is done when 35% or over, of the cargo is lump ore), and the last quartering—or about 100 lbs. is saved and put into cans.

The amount of ore taken for each sample before mixing and quartering, depends upon the tonnage sampled, and as this varies, it is impossible for us to give you the exact weights, but, as a rule, 45 lbs. to 55 lbs. is taken from each hatch. The last two opposite quarters are taken to our crushing and drying house on the docks, weighed and dried at 212°; it is again weighed when dry and the difference is the amount of moisture in the cargo.

The sample is then taken and crushed in a Gates crusher, thoroughly mixed as described above, and about 10 lbs. to 15 lbs. is sent by express to our laboratory for analysis—the sam-

pler keeping in reserve one-half of the last quartering—so that we can call for this should anything happen to the portion shipped.

The advantage, in our opinion, of having these drying and crushing plants on the docks is that a larger sample can be mixed in the dried and crushed state, better than the wet ore as it comes from the boat. Determining the moisture at the docks avoids all accidents that might happen to an undried sample in shipment and gives the proper percentage of moisture in each cargo on its arrival at the unloading dock.

CONCLUSION.

In summing up the question of sampling all grades of iron ores that are delivered at lower lake ports, it is a difficult matter for us to state all conditions and variations that occur in this business. As a general rule, no two boats are unloaded under exactly the same conditions, and no two cargoes of the same ore present the same surfaces, so it is impossible for us to instruct our samplers along any one general rule for sampling, other than those given above, which embrace, in a measure, the fundamental principles of sampling that we have adopted.

By employing intelligent men and instructing them generally about sampling, we leave the detail and conditions to their better judgment, of course, keeping them well under our eye and inspecting their work often.

We believe firmly in large samples and endeavor in all cases to take them. By the term "Large Samples", we mean 300 lbs. to 1,500 lbs. to be taken for a sample. Of course, the amount depends upon the tonnage sampled, but roughly figuring the amount, we should say one-quarter of a pound per ton, this giving a sample that is a representative one. With the rapidity with which the boats are now being unloaded, it takes a constant watch on the sampler's part to be on hand to sample the ore when the worked surfaces present the best faces and those that, when sampled, will give an average of the entire cargo.

Before the docks installed the present fast unloading ma-

chines, we used to take three rounds for each sample—sampling the ore in the boats when one-quarter unloaded and again when one-half out and a third time when three-fourths out—mixing all three samples together for our final sample, but now the time required for unloading is so short that three rounds is entirely out of the question. We believe and have proven beyond a doubt that one large sample taken when the boat is about one-half out gives the proper analysis of the ore.

We realize the importance and responsibility placed upon us in the sampling and analyzing of these different grades of iron ore that are sold on our analysis, and, therefore, are taking every advantage possible to adopt new and change old methods that best suit the conditions now before us in the question of sampling.

Preparation of Sample on Arrival at Laboratory—The samples received at our laboratory having been dried at the docks, need no further drying and are run through a crusher that crushes them up until the ore will pass through a 15-mesh sieve. After crushing the sample, it is mixed on oil cloth by rolling and also by pouring the ore from one pile to another; opposite quarters being taken and mixed as above, until about five ounces are left. This is placed on a chrome steel plate and bucked down until all the sample passes through a 100-mesh sieve and thoroughly mixed by rolling. About one ounce of this ore is dried in a water bath at 212°F., placed in a bottle and corked tightly and allowed to cool. From this dried sample, all determinations are made.

We submit below the methods used in our laboratory for analyzing an iron ore and those that are accurate and at the same time rapid.

DETERMINATION OF IRON.

Weigh $\frac{1}{2}$ gram of ore into No. 0 beaker, dissolve in hydrochloric acid with the addition of a small amount of stannous chloride, reduce with stannous chloride while hot; transfer to No. 4 beaker, add 10 to 15 cc. mercuric chloride and dilute to about 400 cc.; add 10 to 15 cc. manganese sulphate

mixture and titrate with permanganate. Mercuric chloride is a saturated solution and manganese sulphate mixture, we make as follows: Dissolve 800 grams in 5,550 cc. water, add 1,650 cc. phosphoric acid and 1,600 cc. sulphuric acid. Permanganate is made to have 1 cc. equal 1%, using $\frac{1}{2}$ gram of ore.

DETERMINATION OF PHOSPHORUS.

Dissolve 4 grams of ore in hydrochloric acid, evaporate to 5 or 10 cc., add 40 cc. nitric acid concentrated; evaporate to about 15 cc., dilute and filter; add ammonia until it sets to stiff jelly, then add a few cc. in excess. Re-dissolve with nitric acid, heat to 85°C and precipitate with molybdate solution, made as follows: Dissolve 400 grams molybdic acid in 1,600 cc. ammonia, 96 specific gravity and add to 6,000 cc. nitric acid, 1.20 specific gravity. Add 40 cc. of this solution and shake five minutes and let settle; filter, wash with a solution of ammonium sulphate (25 grams of the crystals, 50 cc. sulphuric acid, 2,500 cc. water). Dissolve, precipitate in flask with ammonia (1 part ammonia, 3 of water); wash filter twice with water; add 10 grams mossy zinc and 80 cc. sulphuric acid (1 part sulphuric acid, 3 parts water); heat 15 minutes, filter through cotton, wash with water and titrate with permanganate, using same solution as used for iron determination—viz. 1 cc. equals 1% iron on $\frac{1}{2}$ gram of ore. Multiply number of cc. used by .2035—result is phosphorus.

In ores which retain some of the phosphorous in the residue, this is ignited over the blast for about 5 minutes in crucible; then transferred to beaker and boiled with 10 cc., 1.20 specific gravity; nitric for 5 minutes and filtered into main solution.

DETERMINATION OF SILICA.

Weigh 1 gram of ore, dissolve in hydrochloric acid, add a few drops of nitric acid and evaporate to dryness; take up in hydrochloric acid, filter. Burn off filter in platinum crucible and fuse with carbonate of soda. Dissolve in weak hydrochloric and evaporate to dryness. Moisten with hydrochloric

acid, add hot water, filter, wash with hot water and weak hydrochloric, ignite in crucible and weigh as silica.

DETERMINATION OF MANGANESE.

Dissolve $\frac{1}{2}$ to 2 grams of ore in hydrochloric, add 5 to 10 cc. sulphuric acid, evaporate until fuming freely; cool, dissolve in water, transfer to $\frac{1}{2}$ liter flask, precipitate iron with zinc oxide suspended in water, dilute to mark and filter; measure off 2 portions of 200 cc. each and titrate each portion. Multiply number of cc. used by .1473 and divide by number of grams represented in solution. The result is manganese.

DETERMINATION OF ALUMINA.

Dissolve 1 gram ore in hydrochloric, evaporate to dryness, take up in hydrochloric filter, fuse residue; dissolve fusion in weak hydrochloric, evaporate to dryness, moisten with hydrochloric, dissolve in hot water, filter into first filtrate, neutralize with ammonia, add 3-10 cc. hydrochloric, dilute to 450 cc.; two grams sodium phosphate in solution, stir until solution is clear, add 10 grams hypo-sulphite of soda and 15 cc. acetic acid 30%; let stand 15 minutes, then boil 15 minutes, filter, wash with hot water, dry, ignite and weigh as aluminum phosphate.

DETERMINATION OF LIME AND MAGNESIA.

Dissolve 1 gram of ore in hydrochloric, evaporate to dryness, re-dissolve in hydrochloric, dilute, filter, fuse residue with sodium carbonate, dissolve in weak hydrochloric, evaporate to dryness, cool, moisten with hydrochloric, dissolve with water, filter and wash into first filtrate, heat to boiling, precipitate iron with ammonia, filter while hot, wash several times with hot water, add a few cc. of ammonia to filtrate, heat to boiling, add about 10 cc. hot ammon oxalate, boil 5 minutes, let settle, filter, wash with hot water. After thoroughly washing beaker and precipitate, transfer precipitate to beaker in which precipitation was made; wash filter with weak sulphuric acid; then add 15 cc. concentrated sulphuric acid, heat to 70°C . and titrate with permanganate used for iron determination, 1 cc. equals .0005 grams iron. Multiply result by .2500. Result is oxide of lime.

DETERMINATION OF MAGNESIA.

Cool, filtrate from lime; add 10 cc. concentrated solution of sodium phosphate and ammonia—equal to about 1-10 the bulk of solution; stir well, let stand in a cool place over night, filter, wash with 10% ammonia, ignite in porcelain crucible and weigh. Multiply weight by .36036. Result is magnesia.

DETERMINATION OF SULPHUR.

Dissolve 3 grams of ore in aqua regia, evaporate to dryness, take up in hydrochloric, evaporate a second time, take up in hydrochloric and filter. Precipitate with barium chloride while hot, let settle and filter; wash with cold water and weak hydrochloric, ignite and weigh as barium sulphate. It is always best to test your acids, and if sulphur is found, determine amount and deduct from results.

DETERMINATION OF LOSS BY IGNITION.

Weigh 1 gram of ore in platinum crucible, heat over blast lamp about five minutes; cool and weigh; difference is organic and volatile matter.

NOTES ON SOME OF THE RECENT CHANGES IN
THE EQUIPMENT OF THE REPUBLIC
MINE, REPUBLIC, MICH.

BY FRANK H. ARMSTRONG, VULCAN, MICH.

Prior to 1902 the Republic Iron Co., operated six power plants which were designated as follows:

"Water Works", an air compressor plant driven by water wheels, with an engine and boiler plant to help during low water. "Allis Plant", a cross compound two-stage air compressor. "No. 5", a four-drum hoisting plant, and small electric lighting outfit. "No. 8", a Cornish pump and bucket hoist. "Ely Engine House", originally a four-drum, but for several years a two-drum hoisting plant. "Crusher", a plant for crushing ore.

The first change of any moment undertaken was modernizing the plant at the waterworks. The original plant installed in 1876 was in two units, each consisting of a 66" Swain vertical turbine connected by bevel and spur gears to a 28"x60" duplex single stage compressor. The air pressure carried was 40 lbs. and in 1888 the cylinders were bushed to 20" after which the air pressure developed was 60 lbs. The foundation of these compressors was a frame work of structural steel over the tail-race. The sides of the head-race, as well as the floor of the compressor house, was from 2 to 3 ft. lower than the top of the dam, the latter having been raised a few years after the installation of the compressors. Because of this, a loss in head of from 2 ft. during low water to 5 ft. during high water was sustained at the guard locks. A loss of head of from 1½ to 2 ft. was also sustained because of obstructions in the tail-race. The available head on these wheels was 21 ft. but the head

used was never more, and often less than 18 ft. because of the above reasons. The first work done was clearing the obstructions in the tail-race and raising the sides of the head-race.

The foundation for the new compressors was built on solid ground to one side of the flume, after which the building over the old compressors was moved over the new foundation. The new compressors were then erected and piped up ready for service while the old plant was running in the open. When the compressors were ready, the old plant was thrown out, the new wheels put in the flume, and connected by rope drives to the compressors.

The compressors, shown in Fig. I., are Ingersoll-Sergeant piston inlet two-stage machines, one right and one left, i. e. They were built so that the two high pressure cylinders would be together when they were erected thus allowing less distance between centers of rope wheels, a shorter water wheel shaft on the compressor farthest from the flume, and permitting the low pressure cylinders to be near the outside walls, making a short, direct, intake connection to the outside air possible.

The cylinders are $20\frac{1}{4}$ " and $32\frac{1}{4}$ "x36", and have a displacement of 2,540 cu. ft. at 78 R. P. M.

The inter coolers for these compressors are a horizontal type, placed between the sides of the foundations in the basement, low enough to allow water from the head-race to flow through them without pumping. A small duplex pump run by air, supplies the jacket water.

The rope wheels are 16 ft. in diameter grooved for fourteen $1\frac{1}{2}$ " ropes. The rope drive is of the American system, one continuous rope. The tightener was put in on an inclined track in order to clear the roof trusses.

Each compressor is driven by a 51" horizontal McCormick turbine with an elbow and draft tube made by S. Morgan Smith & Co. The turbine shaft is supported by two adjustable lignumvitae bearings in the flume, one in the neck of the elbow, one in a yoke on the inside of the elbow and by ring oiling bearings outside the flume in the wheel pit.

The flow of water into the wheel is controlled by an

annular ring which slides parallel to the shaft. Two draw rods, brass covered, run through stuffing boxes into the wheel pit where racks and pinions are used to operate them. This arrangement allows all the gate gearing to be outside of the flume where it is accessible at all time.

Each wheel develops 380 H. P. under 21 ft. head and runs 145 R. P. M. The rope wheels on the water wheel shaft are 103" in diameter, giving a rope speed of 4,000 ft. per min.

With the new plant, a greater head than 21 ft. could be used to advantage. This could be obtained either by raising the old timber dam, which was 800 ft. long and in very poor condition, or by building a new one.

In the spring of 1904 a portion of the old dam washed out and it was not deemed advisable to repair it permanently and raise it 3 ft. as well, so a new concrete dam was decided upon. The wash-out was repaired temporarily and all bad leaks stopped, making a fairly tight coffer dam. Work on the new dam was then started some 300 ft. below the old one, where the channel is much narrower.

The form of the section of the dam and resultant pressure are shown in Fig. II. This form is not the most economical of material but was used because of the ease with which large gate area could be provided. (Shown in Fig. III.) The spill-way is 130' long in which are three gates 10' deep by 12' wide. The top of the dam is very little below the top of the flume, the large gate way being depended upon to prevent the water rising much above the top of the dam. This construction was preferred to flashboards.

In the spill-way, abutments and wings there is approximately 700 cu. yds. of concrete. The total cost of this dam including all excavating, building of forms, gates, and concrete was approximately \$5 per cu. yd. The head at present, available is about 24 feet.

ELECTRIC EQUIPMENT.

Until the fall of 1903 a small Brush constant current dynamo driven by a 12"x36" Corliss engine, furnished current for

Section of Spillway.

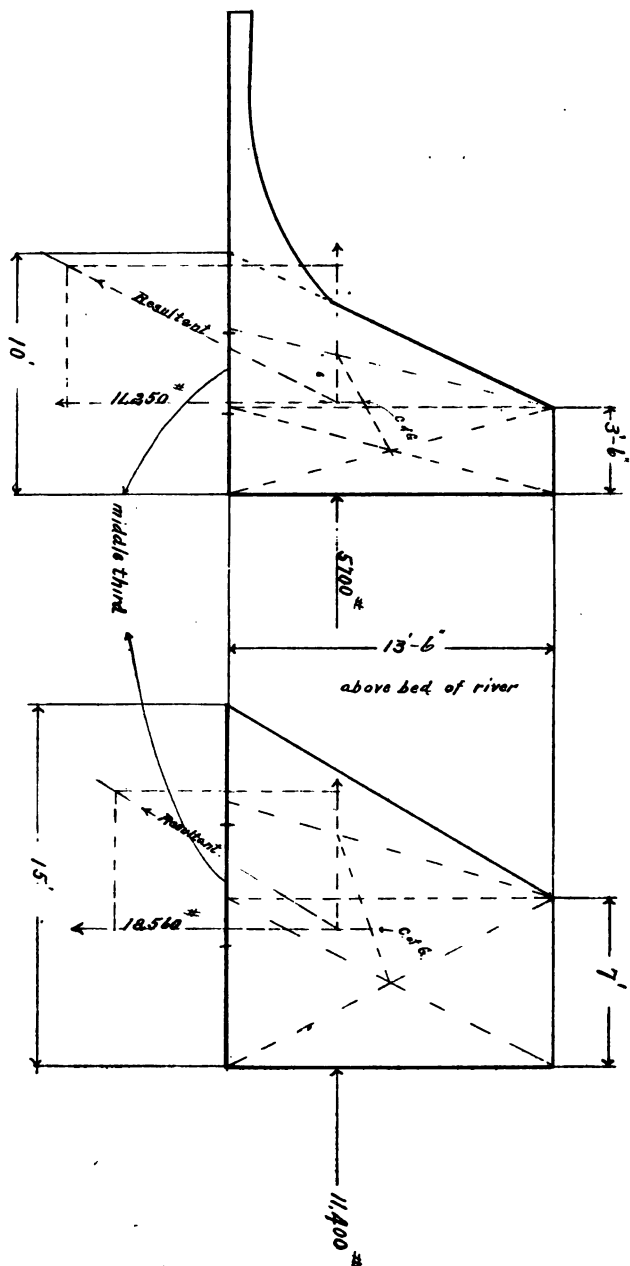


Figure II

Section near Gateway.

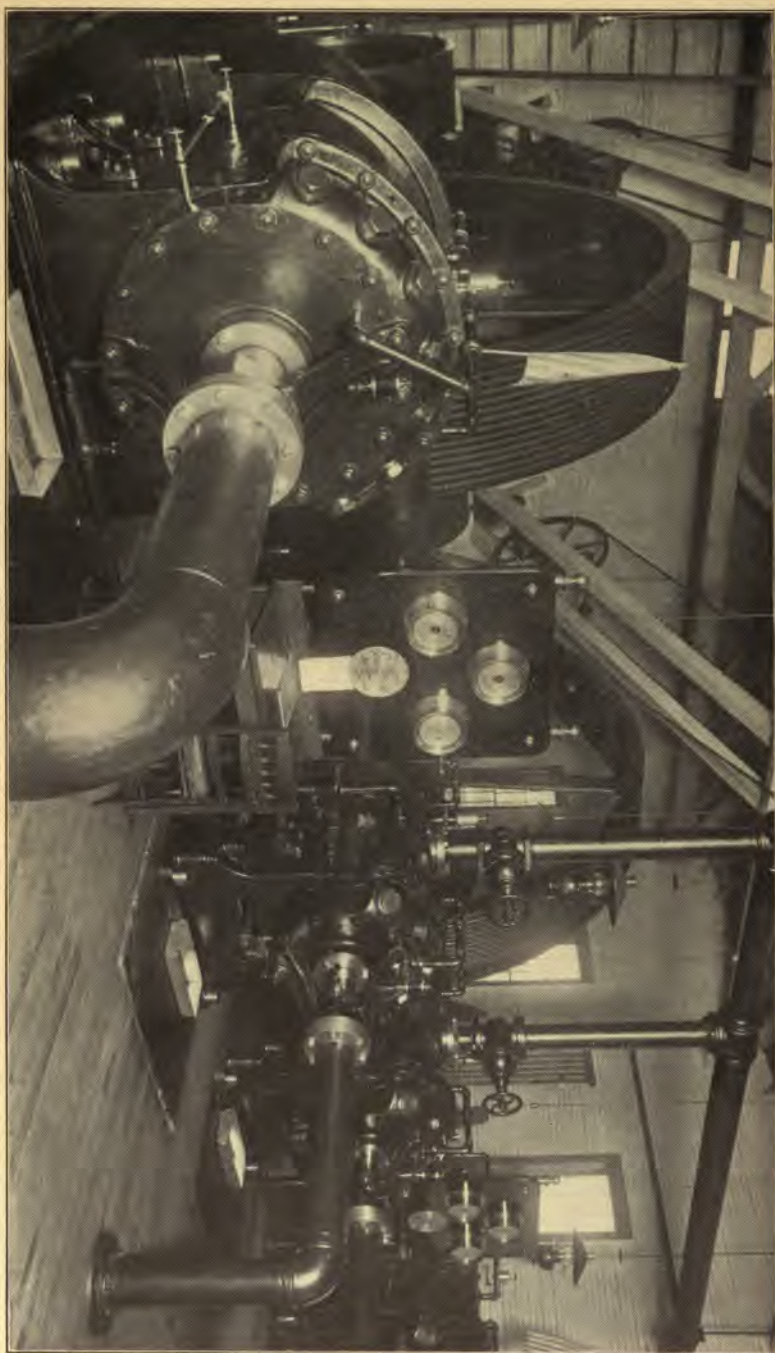


Fig. 1.
COMPRESSOR PLANT, REPUBLIC MINE.



Fig. VI.
ELECTRIC PUMP, REPUBLIC MINE.



Fig. VII.
AERIAL TRAM, REPUBLIC MINE.



Fig. III.
DAM, REPUBLIC, MINE.

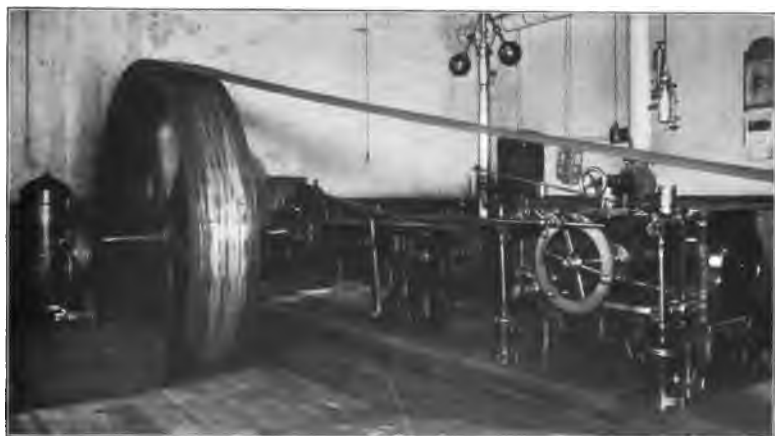


Fig. V.
GENERATOR, REPUBLIC MINE.



Fig. VIII.
COAL POCKET, REPUBLIC MINE.



Fig. IX.
STEEL SHAFT HOUSE, REPUBLIC MINE.



Fig. IV.
SWITCHBOARD, REPUBLIC MINE.



Fig. X.
HOISTING PLANT, PASCOE SHAFT, REPUBLIC MINE.

arc and incandescent lighting. This dynamo was replaced by a General Electric 150 K. W. revolving field, compensated type alternating current generator running 600 R. P. M. and generating a 3-phase 60 cycle current at 2,300 volts. The switchboard for the new generator contains 3 panels; a generator panel, one double feeder panel, and one single feeder panel, shown in Fig. IV.

On the generator panel are 3 ammeters, a volt meter, 2 indicating wattmeters, Rheostat and the necessary switches. The double feeder panel has 6 fuse blocks, 2 ammeters, 2 switches, and the single feeder panel, 3 fuse blocks, 1 ammeter, and 1 switch. Three sets of distributing lines leave the generator house, one from the right side of the double feeder panel to No. 9 electric underground pump, one from the left side of double feeder panel to surface motors, and one from the single feeder panel to the lighting circuit.

New boilers having been installed in this house the pressure on the 12"x36" engine running the generator was increased from 70 lbs. to 130 lbs.

In order to get a proper belt speed the diameter of the fly wheel was increased from 10 ft. to 11 ft. by hardwood lagging, (shown in Fig. V), and the engine speed increased to 135 R. P. M. Some doubt was entertained as to the reliability of a Corliss engine running at this speed. A little trouble was experienced the first day with the dash pots, but after renewing the leather packing in them, the engine gave no further trouble. This electric outfit drives the following motors:

One 50 H. P. form L Induction motor running 720 R. P. M., driving an underground pump. One 10 H. P., 1,200 R. P. M., also running an underground pump. One 7½ H. P., 1,200 R. P. M., running the machine shop. One 20 H. P., 900 R. P. M., running the carpenter shop and coal tram. One 30 H. P., 900 R. P. M., form M. variable speed Induction motor, running a surface tram.

The pumping problem at Republic is quite insignificant compared with the majority of iron mines. An average of 75

or 80 G. P. M., with a storage capacity ample to allow a stoppage of pumping for 2 or 3 days. This water was originally handled by a Cornish pump, the rods of which worked in a shaft having 7 slight bends in it. None of these bends were made by joints or bobs, but by forcibly springing the rods, thus increasing the friction very much. The pump was run by a 20"x30" flat slide valve, link motion engine running on a steam consumption of 56 lbs. per I. H. P. per hour.

The new electric pump (Fig. VI.) installed on the 1,153' level is a Deane 4¾"x12" vertical single acting triplex double back geared to the 50 H. P. motor mentioned above. This pump runs 36 R. P. M. throwing 90 G. P. M. A check valve in the discharge line and a by-pass between the discharge and the suction allows the pump to be started with only the friction load.

The wires are led to the pump room down the shaft through a 1½" wrought iron pipe. Half way down the shaft the pipe enters a cast iron junction box some 6" square by 4 ft. long, where a splice is made and the weight of the lower half of the wires is supported. The only fault found with this pump is the noise it makes. The motor pinion is rawhide and the second pinion fibre, gears are cut. The efficiency of motor, and pipe line is 65%, i. e., the work in water delivered at the top of the shaft is 65% of the work leaving the transformers.

The 20 H. P. motor in the carpenter shop drives a planer, band saw, rip saw, boring machine and by means of a wire rope transmission, an aerial wire rope tram. The tram is used to haul coal from the coal dock to No. 5 engine house, a distance of about 1,200 ft. Two 1¼" wire ropes were stretched over the supports 6 feet apart and one bucket is used on each rope.

The hoisting rope makes one-half lap around a 6 ft. wood filled sheave at the lower end of the tram, which sheave is driven by a double bevel paper and iron friction gear (Fig. VII.) The two bevels are run by the rope transmission from the carpenter shop. The two buckets run in balance, one dumping at No. 5, while the other is being filled at the coal dock.

One of the paper frictions pulls the hoisting rope in one direction, the other in the opposite direction.

The buckets are automatic, being hung from a point 1" below the center of the end. The shape of the bucket is shown in Fig. VII. The top is wider than the bottom thus making the load top heavy although the bottom is heavier, when the bucket is empty. Therefore when the catch is released, the bucket dumps and immediately rights itself. The catch that keeps it from dumping, extends below the bottom several inches. As the bucket comes toward the pocket, Fig. VIII., with its load of 1,000 lbs., the sag in the rope is enough to allow the catch to strike the edge of the pocket. The bucket, then being dumped, is so much lighter, that the tension of the supporting rope raises the bucket enough for the catch to clear the pocket going back. The speed of hoisting is 450' per min.

PASCOE TRAM.

The hauling of the ore from Pascoe shaft house to the pocket and stock pile is done in an automatic dump car, shown in Fig. IX., run by a 30 H. P. reversible, variable speed motor. The car is pulled by an endless rope which makes 4 half laps around a 3 ft. driving drum, and three half laps around three independent sheaves thus largely eliminating the differential action caused when two solid drums are used instead of one drum and independent sheaves as above. The motor is geared to the drum shaft, no friction clutch being used. The speed of the car is 1,200 ft. per minute.

PASCOE SHAFT.

The hoisting from Pascoe shaft was originally done from Ely engine house, with a small skip running 500 ft. per min., over a very crooked skip road.

Because this shaft was to be the principle shaft of the mine, and to allow the closing down of another engine house, a new hoist was put in an addition to the building over the Allis compressor. While this hoist was being erected the skip road was straightened, widened, a double track laid, and a new steel shaft house erected. (Fig. IX.) The foundation for the shaft

house was built in winter. A rough shed was built over the excavation and out over the top of the shaft which has a strong up cast. This up cast was warm enough to prevent any freezing. The shaft house was built by the Wisconsin Bridge & Iron Co.

The hoist for the Pascoe shaft is a duplex direct acting Sullivan Corliss plant consisting of two 24"x48" engines and two drums 8' diameter by 9' face. (Fig. X.) Each drum has independent friction clutches and brakes. The clutches are operated by a vertical, and the brakes by horizontal clutch engines, supplied by auxiliary oil cylinders for rendering the motion of the clutch smooth and uniform.

The brakes are bands of machine steel, the blocks of wood being bolted to the drums. The brake levers are so arranged that they can be used as a steam brake and gravity release, or a gravity brake and steam release. The latter arrangement is now in use. The steam valves operating both clutch and brake cylinders are fitted with differential valve gears, so that the pistons follow the movement of the engineers' hand lever.

These five auxiliary engines, two clutch, two brake and one reverse, are so piped that air or steam can be used to operate them. Air is used during the week and steam for Sunday work, or when the compressors are not running. Each drum is provided with an automatic stop that sets both brakes should the skip be hoisted too far.

An automatic throttle closing device closes the throttle at such a point that the skip barely comes into the dump. This is adjustable and is set by trial. A by-pass valve operated by the foot is used to give the engines a little more steam, if needed, to complete the hoist. A relief valve is located on the side of each throttle which, when opened, prevents any steam that may leak past the throttle, from turning the engine. This is used a great deal in place of the brakes. When lowering men, or timber, the load decreases rapidly as the ropes become balanced and soon becomes a negative load. The engineer then opens these relief valves and reverses the engine. By partially

closing the relief valves the engine compresses air, checking the speed very smoothly and without any wear on the brakes.

The net load hoisted is 10,000 lbs. on an incline of 45°. Two governor pulleys were furnished, one giving a hoisting speed of 1,200 ft. per min., and one 1,800 ft. per min. The 1,200 ft. speed is in use at present.

The Sullivan hoist put one of the two drums in Ely engine house out of commission, and the other, with one of the engines, was moved into another addition to the building containing the Allis compressor and the Sullivan hoist.

A rope line from this drum was run across the end of the lake to West Republic shaft house a distance of approximately 1,900 ft. The drum and shaft house are both on small hills and are of such a height that if the rope was carried in a straight line from the top of the drum to top of the shaft house the supporting pulley stands would be from 50 ft. to 65 ft. high. It was suggested that a catenary curve be used thus allowing the use of low pulley stands. Stands 15 ft. to 18 ft. high could readily be built permitting a sag in the rope of from 40 ft. to 50 ft. at the center. With a 50 ft. sag at the center of the span, the maximum allowable tension is found from the formula $t = \frac{ws^2}{8h}$

in which w is the weight of rope per ft., s the span and h the sag of the rope in the center. Both in feet.

The span of the catenary was 1,800 ft, so for a 50 ft. sag the tension required to lift the rope off the pulleys would be more than 20,000 lbs. very nearly the safe working tension of a 1¼" rope. The pulley stands were put in on this plan and the rope was run, against the advise of many, *over* the pulleys instead of *under* them, and the rope has not been seen to lift at any time.

These changes have eliminated the need of three boiler houses, and two engine houses, with their accompanying engineers, brakeman, fireman, and coal haulers, *more than doubled* the efficiency of the water works, and enabled the shops, pumps and trams to be run, and light furnished with approximately half the steam used originally for pumping.

DISCUSSION OF MR. BATTU'S PAPER ON STEAM
REGENERATOR FOR HOISTING ENGINES
BY THE RATEAU SYSTEM.

MR. NELSON: For instance, if we wish to install an accumulator in connection with a hoisting engine developing 3,000 H. P. can you give us an idea of what size the accumulator ought to be?

MR. BATTU: The size of the steam regenerator depends on the quantity of steam to be regenerated and also on the duration of stops of the main engine. I gave in my paper a formula for calculating such weight of heat retaining bodies.

MR. NELSON: Say about 42,000 pounds?

MR. BATTU: A steam regenerator of the water type would contain approximately 55 tons of water, and would take care of interruptions of somewhere around two minutes. The over-all dimensions of the regenerator would be about 27 feet in length and 11 feet in diameter. Under such conditions the low pressure turbine would have an output of 1,500 H. P., if the vacuum available was of approximately 27 inches.

MR. NELSON: If the back pressure valve on the regenerator was set to blow off at 6 or 7 pounds above atmosphere, how long can you retain the steam pressure in the regenerator after the hoist is shut down without admitting an additional amount of steam to the regenerator?

(At this point Mr. Battu referred to a diagram, showing a drop in pressure of 2 pounds, after the hoisting engine had been shut down 7 minutes, when the heat absorbed by the evaporation of the water will have reduced its temperature from the temperature corresponding to steam at 6 or 7 pounds gauge to that of steam at 14.7 pounds absolute.)

MR. BATTU: In practice, an accumulator never has to take care of stoppages of over 4 or 5 minutes. The boilers,

after such a period, can afford to blow off steam through the reducing-valve instead of through the safety-valve. By increasing the size of the regenerator in proportion to the intervals between hoisting one could build a regenerator suitable for ten-minute interruptions, if desirable.

MR. NELSON: What is the difference, in heat-retaining qualities, between pig iron and water, when used in your regenerator? Pig iron is, of course, expensive, whereas water is not, and the heat-retaining qualities of pig iron ought to be greatly in its favor to make it advantageous to use it, instead of water.

MR. BATTU: The specific heat of rough iron is 0.11, the specific heat of water being 1.

The necessity of utilizing large surfaces brought Prof. Rateau to utilize trays of cast-iron, so as to have an extremely rapid exchange of temperature between the exhaust steam and the heat.

MR. NELSON: As long as water can be had at no expense, why is it not advisable to use water entirely, and not use iron at all?

MR. BATTU: The water type of steam regenerator is now in general use in Europe.

MR. NELSON: How many H. P. can you develop with 30,000 lbs. of steam per hour?

MR. BATTU: 1,000 H. P., with a vacuum of $26\frac{3}{4}$ ".

MR. NELSON: That means that, for every 30,000 lbs. of steam that now goes to waste, you can utilize 1,000 H. P. of energy by the regenerator system.

MR. BATTU: Yes.

MR. NELSON: On this blue print diagram just handed me is shown, approximately, an absolute pressure of 17 lbs., or 2 lbs. above atmosphere. This shows a lower back pressure than we have to contend with on hoisting engines generally. In starting the load from the bottom with a first-motion hoisting engine the back pressure will in many instances exceed 8 or 10 lbs. for several revolutions, so that a back pressure of 2 lbs.

gauge above atmosphere cannot be raised as an objection to your accumulator system?

MR. BATTU: It is generally advisable to load the exhaust valve leading to atmosphere with one, two or three pounds, as it is absolutely of no incumbrance to the main engine, but in cases where it would be advisable to give a slight vacuum to the main engine, the steam regenerator will work perfectly well. For instance we have several turbines running on pressures of .65 of one atmosphere absolute.

MR. NELSON: We cannot figure on exhausting from hoisting engines at a pressure lower than atmosphere. The back pressures are always much above that. The only time that a turbine would be called upon to run at a pressure much below the atmosphere would be when a hoisting engine had been standing still for a sufficient length of time for a turbine to use up the exhaust steam stored in the accumulator. Then, Mr. Battu, after the steam stored up in the regenerator has been used, it would be necessary to supply steam to the turbine from some other source. The steam, of course, would have to be taken direct from the boiler. In that case could we use an automatic valve so as to admit the boiler pressure until the hoisting engine started, and after the pressure in the accumulator exceeded a certain amount, the supply of steam from the boiler would be automatically shut off.

MR. BATTU: If the stoppages of the hoisting engine are to be of such long duration as to necessitate the use of a large amount of live steam, it would be advisable to employ a system of high and low pressure turbines, the admission of high pressure steam being automatically allowed to the high pressure part of the turbine and the exhaust to the low pressure part that receives the exhaust from the regenerator; but to simplify the apparatus it has been found advisable, when the duration of stops is not sufficiently long, to have an automatic reducing valve admitting the steam direct from the boiler to the low pressure turbine. Certainly the efficiency of the high pressure steam going through high and low pressure turbine would be a

great deal better than when utilizing the live steam after its pressure has been reduced by the reducing valve. Nevertheless the steam consumption of the low pressure turbine will be lower when utilizing live steam that has been reduced in pressure by the reducing apparatus. As a matter of fact, a turbine using 30 pounds of steam when receiving steam from the regenerator will need only 22 pounds of steam per H. P. when receiving steam from the reducing valve.

MR. NELSON: We wish to refer again to the diagram that shows a back pressure of 2 pounds above atmosphere. That is, approximately, 17 pounds absolute, and we would like to know at how low a pressure absolute it is possible for a turbine to run and maintain full speed?

MR. BATTU: A fluctuation of 1 pound in pressure can be taken care of very easily by the governor of the turbine. Our turbines in use on steam regenerators can maintain a variation of speed within 1% when the load is thrown on and off successfully.

MR. NELSON: The above explanation refers to the variation in speed from full load to no load, but what we would like to know is, what is the lowest possible pressure at which you can run your turbine? Will it be 4, 5 or 6 pounds absolute, or more, or less?

MR. BATTU: The turbine referred to has been built so as to give its full load when receiving steam at 90% of atmospheric pressure. If the pressure of steam at admission in the turbine was under 90% of atmospheric pressure, full load could not be maintained, but this never occurs as live steam admission through the reducing-valve would automatically take place.

MR. NELSON: Can the turbine be so designed that it will run with a pressure considerably lower than atmospheric pressure, so as to dispense with the necessity of admitting live steam from the boiler when the pressure in the regenerator drops a small amount below atmosphere.

MR. BATTU: This means to say that you would propose

to have the low pressure turbines giving their full load when receiving steam at a fraction of atmospheric pressure, and that also you would agree to set the blow-off on the regenerator at, say, 2 pounds gauge, then the regenerator would give up steam at pressures varying from 17 to $7\frac{1}{2}$ pounds absolute.

(1.) Do you think the main engine could work without giving trouble when running under these conditions of back pressure? The hoist would be running condensing and non-condensing during its operation.

(2.) The regenerator can regulate the pressures with great accuracy. Any given pressure can be steadily maintained between very narrow limits. If longer stops are to be expected, the only way to obviate the employment of live steam is to increase the weight of the heat accumulator.

(3.) The turbine being constructed to give full load when receiving steam at one-half atmosphere would have to utilize only a portion of the steam when the pressure in the regenerator would be more than one-half atmosphere. The excessive steam would be blown off through the relief valve. The principle involved in the regenerator is the accumulation of heat and not of steam. Steam cannot be accumulated in a reservoir without increasing the pressure and thus creating a back pressure on the main engine. The idea of utilizing large fluctuations of pressure in the regenerator involves great losses of heating and would thus diminish largely the power available by the Rateau process.

If one would think it advisable to have, say one-half atmosphere only as back pressure on the main engine, the steam regenerator would have to be figured as accumulating heat under one-half absolute pressure, and the temperature of the regenerator would be maintained between a range of 5 or 6 degrees without any difficulty.

MR. NELSON: We understand, of course, that the efficiency of the turbine, will be impaired by the drop in pressure. But as we are utilizing, for driving the turbine, exhaust steam that cannot be used for other purposes, the impairing of the

efficiency could not be considered as objectionable as the admission of live steam into the turbine after the steam pressure in the accumulator drops slightly below atmosphere. We should think, off-hand, that it would be better to design the turbine so that it would run at a pressure considerably lower than atmospheric pressure, and avoid as much as possible the introduction of live steam into the turbine.

MR. BATTU: The thermic efficiency of the turbine, after utilizing a lower pressure than one atmosphere absolute, would not be impaired, but increased. The amount of regenerated steam available to the turbine would be diminished if large variations of pressure were to be allowed in the regenerator. In steel works and mines we are not trying to explain the possibility of the Rateau Process—the demonstration is actually made—but we have to show the maximum efficiencies which can be obtained. The proposition of wasting steam to obtain longer durations of activity in the regenerator, when the capacity of that apparatus can be increased sufficiently to take care of these conditions, would not be at all admissible.

Do not forget that what we claim is, that the low pressure turbine will in all cases render available more effective H. P. than the primary engine itself, in the case of a hoisting engine particularly.

The hoisting engine is, of course, under the most trying conditions, as the load is practically varying continually. On the other hand the turbine is in the most ideal conditions. The load is constant and the low pressures utilized are such that the drop in temperature per pound drop in pressure is practically five or six times as high as the drop of temperature per pound drop of pressure in the main engine.

MR. NELSON: I understand, then, that you wish to confine yourself to a pressure not lower than the atmospheric pressure with these machines. You do not advise going below this amount of pressure to a great extent?

MR. BATTU: If the main engine is not to be benefited by the vacuum it would be a vast error to run the turbine under at-

mospheric pressure. The result would be to diminish the efficiency of the plant.

What I would advocate—and I refer to my paper—is to allow some pounds of back pressure. This will in no way interfere with the economy of the hoisting engine and increase the available power in the turbine.

MR. NELSON: Now at some of the copper mines where they are using hoisting engines of enormous size and hoisting from great depths, with your method enough energy could be utilized to furnish electric light and electric power for tramming and other work. About what would be the cost per KW. or per H. P. of this installation?

MR. BATTU: In the copper region, the power which could be rendered available in utilizing the exhaust steam of the hoists would vary from 400 to 200 H. P., depending on the size of the hoist.

The cost of producing power by the Rateau process is the interest on the investment only, plus a small maintenance cost. Steam turbines do not need more lubrication than does an electric generator. There is no boiler maintenance, and no additional fuel to be accounted for. As a matter of fact the condensing auxiliaries ought to be accounted for, but as they can be run by motors from electric generators driven by the turbine, one can see that the power used in condensing is obtained at no cost.

PAST OFFICERS.

PRESIDENTS.

Nelson P. Hulst.....	1893
J. Parke Channing.....	1894
John Duncan	1895
Wm. G. Mather.....	1896
William Kelly	1898
Graham Pope	1900
W. J. Olcott.....	1901
Walter Fitch	1902
George H. Abeel.....	1903
O. C. Davidson.....	1904

(No meetings were held in 1897 and 1899.)

VICE-PRESIDENTS.

1893.		
John T. Jones.	J. Parke Channing.	Graham Pope.
F. P. Mills.		M. W. Burt.
1894.		
John T. Jones.	R. A. Parker.	Graham Pope.
F. P. Mills.		W. J. Olcott.
1895.		
F. McM. Stanton.	R. A. Parker.	Per Larsson.
Geo. A. Newett.		W. J. Olcott.
1896.		
F. McM. Stanton.	J. F. Armstrong.	Per Larsson.
Geo. A. Newett.		Geo. H. Abeel.
1898.		
E. F. Brown.	Ed Ball.	Walter Fitch.
James B. Cooper.		Geo. H. Abeel.
1900.		
O. C. Davidson.	M. M. Duncan.	J. H. McLean.
T. F. Cole.		F. W. Denton.
1901.		
J. H. McLean.	Nelson P. Hulst.	F. W. Denton.
M. M. Duncan.		William Kelly.
1902.		
William Kelly.	Fred Smith.	H. F. Ellard.
Nelson P. Hulst.		Wm. H. Johnston.
1903.		
H. F. Ellard.	James B. Cooper.	Wm. H. Johnston.
Fred Smith		John H. McLean.
1904.		
M. M. Duncan.	F. W. McNair.	John H. McLean.
Fred M. Prescott.		James B. Cooper.

MANAGERS.

1893.		
John Duncan.		James MacNaughton.
Walter Fitch.	William Kelly.	Charles Munger.
1894.		
Walter Fitch.		C. M. Boss.
John Duncan.	M. E. Wadsworth.	O. C. Davidson.
1895.		
F. P. Mills.		C. M. Boss.
Ed. Ball.	M. E. Wadsworth.	O. C. Davidson.
1896.		
F. P. Mills.		Graham Pope.
Ed. Ball.	C. H. Munger.	William Kelly.
1898.		
M. M. Duncan.		Graham Pope.
J. D. Gilchrist.	T. F. Cole.	O. C. Davidson.
1900.		
E. F. Brown.		Walter Fitch.
Ed. Ball.	James B. Cooper.	George H. Abeel.
1901.		
James B. Cooper.		James Clancey.
James MacNaughton.	(One Vacancy.)	J. L. Greatsinger.
1902.		
James Clancey.		Graham Pope.
J. L. Greatsinger.	Amos Shephard.	T. F. Cole.
1903.		
Graham Pope.		T. F. Cole.
Amos Shephard.	Wm. J. Richards.	John McDowell.
1904.		
John McDowell.		William Kelly.
Wm. J. Richards.	John C. Greenway.	H. B. Sturtevant.

TREASURERS.

C. M. Boss.....	1893
A. C. Lane.....	1894
Geo. D. Swift.....	1895-1896
A. J. Yungbluth.....	1898-1900
Geo. H. Abeel.....	1901-1902
E. W. Hopkins.....	1903-....

SECRETARIES.

F. W. Denton.....	1893-1896
F. W. Denton and F. W. Sperr.....	1898
F. W. Sperr.....	1900
A. J. Yungbluth.....	1901-....

LIST OF PUBLICATIONS RECEIVED BY THE INSTITUTE.

American Institute of Mining Engineers, 99 John St.,
New York City.
Canadian Mining Institute, Ottawa..

American Society of Civil Engineers, 220 W. 57th St., New York City.

Institution of Mining Engineers, Neville Hall, Newcastle-upon-Tyne.

Massachusetts Institute of Technology, Boston, Mass.

Chemical, Metallurgical and Mining Society of South Africa, Johannesburg, S. A.

Western Society of Engineers, 1734-41 Monadnock Blk., Chicago.

The Mining Society of Nova Scotia, Halifax, N. S.

Canadian Society of Civil Engineers, Montreal.

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne.

State Bureau of Mines, Colorado, Denver, Colo.

Stahl und Eisen, Dusseldorf, Germany, Jacobistrasse 5.

Reports of the U. S. Geological Survey, Washington,

D. C.

Geological Survey of New South Wales, Sydney, N.

S. W.

Geological Survey of Ohio, State University, Columbus, Ohio.

IRON ORE SHIPMENTS.

LAKE SUPERIOR IRON ORE SHIPMENTS FROM THE DIFFERENT RANGES
FROM 1865 TO 1905, INCLUSIVE:

(Compiled from tonnage as published by Iron Trade Review.)

Total Shipments up to and including						
	1902.	1903.	1904.	1905.	Grand Total.	
Marquette Range.....	(Tons..... 66,706,164 Per ct..... 46.8	3,040,245 12.5	2,843,703 13.	4,210,522 12.2	76,800,634 25.6	
Menominee Range	(Tons..... 42,247,571 Per ct..... 36.3	3,749,567 15.4	3,074,848 14.1	4,495,451 13.1	53,567,437 17.8	
Vermilion Range	(Tons..... 19,061,506 Per ct..... 16.4	1,676,699 7.0	1,282,513 5.9	1,677,186 4.9	23,697,904 7.9	
Gogebic Range	(Tons..... 37,818,274 Per ct..... 31.0	2,912,912 12.0	2,398,287 11.	3,705,207 10.8	46,834,680 15.6	
Mesabi Range	(Tons..... 53,747,807 Per ct..... 69.4	12,892,542 53.1	12,156,007 55.7	20,153,699 58.7	98,950,056 33.	
Miscellaneous	2,320	*17,913	*67,480 .3	*111,391 .3	199,104 .1	
Total Tons.....	219,583,642	24,289,878	21,822,839	34,353,456	300,049,815	
		Decrease from 1902 11.9 p.c.	Decrease from 1903 10.2 p.c.	Increase over 1904 57.4 p.c.		
*Iron Ridge Wisconsin	Tons..... 39,978					
Illinois Wisconsin	Tons..... 71,413					
	Tons..... 111,391					

